MECHANICAL ENGINEERING

GATE | PSUs

MACHINE DESIGN

Volume - I : Study Material with Classroom Practice Questions

Machine Design

Solutions for Vol – I _ Classroom Practice Questions

Chapter- 1
Static Loads

01. **Ans: (d)**

Sol: $t = 0.2$ mm, $d = 25$ mm,

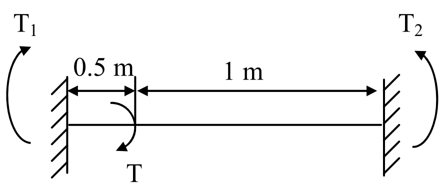
$E = 100$ GPa

$$\frac{M}{I} = \frac{E}{R} = \frac{\sigma_b}{y}$$

$$\sigma_b = \frac{100 \times 10^3 \times \left(\frac{0.2}{2}\right)}{\left(\frac{25}{2}\right)} = 800\,\text{MPa}$$

02. **Ans: (b)**

Sol:



$T = T_1 + T_2$

$\theta = \theta_1 = \theta_2$

$$\frac{T_1 l_1}{GJ_1} = \frac{T_2 l_2}{GJ_2}$$

$$T_1 = \frac{7358 \times 1}{1.5} = 4905.33\ \text{Nm}$$

$$T_2 = \frac{7358 \times 0.5}{1.5} = 2452.66\,\text{Nm}$$

Maximum shear stress

$$\tau = \frac{16\,T_1}{\pi d^3} = \frac{16 \times 4905.33 \times 10^3}{\pi \times 80^3} = 48.8\ \text{MPa}$$

03. **Ans: (a)**

Sol: $G = 0.8 \times 10^3$ MPa

$$\frac{T_1}{J_1} = \frac{G\theta_1}{l_1}$$

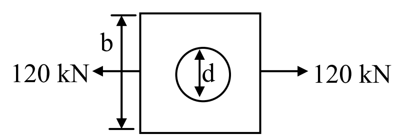
$$\theta_1 = \frac{4905.33 \times 10^3 \times 0.5 \times 10^3}{\frac{\pi}{32} \times 80^4 \times 0.8 \times 10^5}$$

$= 7.62 \times 10^{-3}$ radian

$= 7.62 \times 10^{-3} \times \frac{180}{\pi} = 0.436$ degrees

04. **Ans: (b)**

Sol:



$P = 120$ kN, $t = 13$ mm

$$\frac{120 \times 10^3}{(b-d)t} = 75\,\text{MPa}$$

$$\frac{120 \times 10^3}{(b-22) \times 13} = 75$$

$\Rightarrow b = 145$ mm

05. **Ans: (b)**

Sol: Force applied on the bar

$= 95 \times 100 \times t$ N

Maximum stress induced

$$= \frac{\text{Force}}{\text{Minimum area}}$$

$$= \frac{95 \times 100 \times t}{(100-5) \times t} = 100\,\text{MPa}$$

06. **Ans: (c)**

Sol: By taking moment of force about the axis of fulcrum

$2.25 \times 1.25 = P \times 15$

$P = 1.875$ kN

07. **Ans: (c)**

Sol: The reaction force acting on the pin

$$R = \sqrt{2.25^2 + 1.875^2} = 2.928\,\text{kN}$$

R = Pressure × (Projected area of the pin)

$= 6.5 \times (d_1 \times l_1) = 6.5 \times (d_1 \times 2 \times d_1)$

$(\because l_1 = 2d_1)$

$2.928 \times 10^3 = 6.5 \times 2 \times d_1^2$

$d_1 = 15$ mm

08. **Ans: (a)**

Sol: d = 30mm, t = 3mm

Outer diameter = 30 + 2 × t

= 30 + 2 ×3 = 36mm

Speed ratio = 4:1

$$T = \frac{60 \times 10 \times 10^3}{2\pi \times \frac{2000}{4}} = 190.985\text{Nm}$$

$$\frac{T}{J} = \frac{\tau}{r}$$

Maximum shear stress

$$\tau = \frac{16 \times 190.985 \times 10^3}{\pi\left(\frac{36^4 - 30^4}{36}\right)} = 40.27\text{MPa}$$

Chapter- 2
Theories of Failure

01. **Ans: (c)**

Sol: $\sigma = 60$ MPa, $\tau = 40$MPa,

$S_{yt} = 330$ MPa

According to maximum principal theory

$$\sigma_1 = \frac{S_{yt}}{F.S}$$

$$\sigma_1 = \frac{60+0}{2} + \sqrt{\left(\frac{60-0}{2}\right)^2 + \tau^2}$$

$$= 30 + 50 = 80\,MPa$$

$$\therefore\ 80 = \frac{330}{F.S} \Rightarrow F.S = 4.125$$

02. **Ans: (c)**

Sol: Given $\sigma = \begin{bmatrix} 40 & 0 \\ 0 & -30 \end{bmatrix}$

$\sigma_1 = 40$, $\sigma_2 = -30$, $\sigma_{yt} = 350$ MPa

Max shear stress theory

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{S_{sy}}{FOS} = \frac{S_{yt}}{2 \times FS}$$

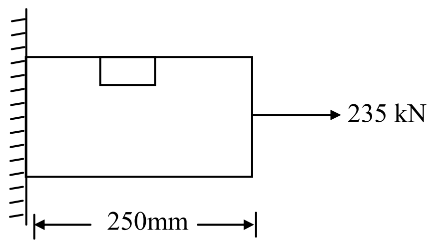
$$\Rightarrow \frac{40+30}{2} = \frac{350}{2 \times FS}$$

$$\Rightarrow FS = \frac{350}{70} = 5$$

03. **Ans: (d)**

Sol: d = 50mm, L = 250 mm, P = 235 kN,

S_{ut} = 480 MPa



According maximum shear stress theory

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{S_{yt}}{2\times F.S}$$

$\therefore \sigma_x = \sigma$ & $\sigma_y = 0$ and $\tau_{xy} = 0$

$$\sigma = \frac{235\times10^3}{\frac{\pi}{4}\times50^2} = 119.68\,MPa$$

$$\tau_{max} = \frac{\sigma}{2} = \frac{S_{ut}}{2\times F.S}$$

$$\frac{480}{2\times F.S} = \frac{119.68}{2}$$

F.S = 4

04. **Ans: (b)**

Sol: F_t = 48 kN $\quad$ S_{yt} = 200 MPa

F_S = 18 kN $\quad$ FS = ?

Since bolts are made of ductile material, so we can use maximum shear stress theory

$$\sigma = \frac{48\times10^3}{600} = 80\ \ MPa$$

$$\tau = \frac{18\times10^3}{600} = 30\,MPa$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{80}{2}\right)^2 + 30^2}$$

= 50 MPa

According to maximum shear stress theory

$$\tau_{max} = \frac{S_{sy}}{F.S}$$

$$\tau_{max} = \frac{S_{yt}}{2\times F.S}$$

$$50 = \frac{200}{2\times F.S} \Rightarrow F.S = 2$$

05. **Ans: (d)**

Sol: Given thin cylindrical shell

d_i = 4.6 m, $\quad$ p = 0.210 MPa

t = 16 mm, $\quad$ S_{yt} = 260 MPa

F_s = ?

$$\sigma_h = \frac{pd}{2t} = \frac{0.21\times4.6\times10^3}{2\times16}$$

$$\sigma_l = \frac{pd}{4t} = \frac{0.21\times4.6\times10^3}{4\times16} = 15.09\,MPa$$

$\sigma_h = \sigma_1$= 30.18 MPa

$\sigma_t = \sigma_2$ = 15.08 MPa

$\sigma_3 = 0$

$$\tau_{max} = \text{Max. of}\begin{cases}\left|\frac{\sigma_1-\sigma_2}{2}\right| \\ \left|\frac{\sigma_1}{2}\right| \\ \left|\frac{\sigma_2}{2}\right|\end{cases}$$

$$\left|\frac{30.18-15.08}{2}\right| = 7.55$$

i.e., $\left|\frac{30.18-0}{2}\right| = 15.09$

$$\left|\frac{15.08}{2}\right| = 7..54$$

$\tau_{max} = 15.09$

According max shear stress theory

$$15.09 = \frac{S_{sy}}{F.S}$$

$$15.09 = \frac{S_y}{2\times FS}$$

$$FS = \frac{260}{2\times 15.09} = 8.62$$

06. **Ans: (c)**

Sol: $\sigma_t = 200\text{ MPa} = \sigma_1$

$\sigma_c = -100\text{ MPa} = \sigma_2$

$S_{yt} = 500\text{ MPa}$

Tresca theory

$$\tau_{max} = \frac{\sigma_1-\sigma_2}{2} = \frac{S_{yt}}{2\times FS}$$

$$\frac{200-(-100)}{2} = \frac{500}{2\times FS}$$

FS = 1.666 = 1.67

07. **Ans: (b)**

Sol: $\tau_{max} = \dfrac{S_{sy}}{FS}$

$$\tau_{max} = \frac{S_{yt}}{2\times FS}$$

But $\tau_{max} = \sqrt{\left(\dfrac{\sigma_b}{2}\right)^2 + \tau^2}$

$$= \sqrt{\left(\frac{55}{2}\right)^2 + (31.5)^2} = 41.81$$

$$FS = \frac{S_{yt}}{2\times\tau_{max}} = \frac{284}{2\times 41.81} = 3.39$$

08. **Ans: (a)**

Sol: $F_T = 20\text{kN}$, $F_s = 15\text{kN}$

$S_{yt} = 360\text{ MPa}$, $F_s = 3$

d = ?

$$\sigma = \frac{F_T}{A} = \frac{20\times10^3}{A} N/mm^2$$

$$\tau = \frac{F_S}{A} = \frac{15\times10^3}{A} N/mm^2$$

$$\sigma_1 \ \& \ \sigma_2 = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\frac{S_{yt}}{FS} = \sqrt{\sigma_1^2+\sigma_2^2-\sigma_1\sigma_2}$$

According to distortion energy theory

$$\sigma_1 = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2+\tau^2} = \frac{\sigma}{2}+\tau_{max} = \frac{\sigma}{2}+R$$

$$R = \sqrt{\left(\frac{\sigma}{2}\right)^2+\tau^2}$$

$$\sigma_{eq} = \sqrt{\sigma_1^2+\sigma_2^2-\sigma_1\sigma_2}$$

$$= \sqrt{\left(\frac{\sigma}{2}+R\right)^2 + \left(\frac{\sigma}{2}-R\right)^2 - \left(\frac{\sigma}{2}+R\right)\left(\frac{\sigma}{2}-R\right)}$$

$$\sigma_{eq} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + 3R^2}$$

$$\sigma_{eq} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + 3\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2} = \frac{S_{yt}}{F_s}$$

$$= \sqrt{\left(\frac{20\times10^3}{A}\right)^2 + 3\times\left(\frac{15\times10^3}{A}\right)^2} = \frac{360}{3}$$

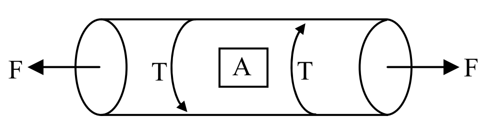
$$= \frac{10^3}{A}\sqrt{20^2 + 3\times15^2} = \frac{360}{3}$$

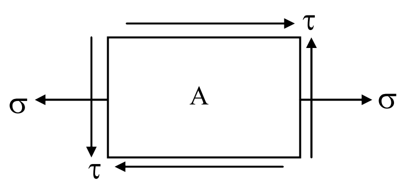
$\therefore$ A = 273.22 mm^2 = (π/4) d^2

$\Rightarrow$ d = 18.65mm

09. **Ans: (b)**

Sol:





FS = 2, S_{yt} = 310 MPa,

F = 40 kN ,

d = 20 mm, T = ?

According to Distortion Energy Theory

$$\frac{S_{yt}}{FS} = \sqrt{\sigma^2 + 3\tau^2}$$

$$\sigma = \frac{F}{\frac{\pi}{4}\times d^2} = \frac{40}{\frac{\pi}{4}\times 20^2} = 127.32 \text{ MPa}$$

$$\frac{310}{2} = \sqrt{(127.32^2 + 3\tau^2)}$$

$\Rightarrow \tau$ = 51.03 MPa

$$\tau = \frac{16T}{\pi d^3}$$

$$\Rightarrow 51.03 = \frac{16T}{\pi\times 20^3}$$

$\Rightarrow$ T = 80157.73 Nmm = 80.157 Nm

10. **Ans: (b)**

Sol: P = 5 kN , d = 10 cm= 0.1 m

Torque, T = 5 × 10^3 × 0.5

S_{yt} = 425 MPa

Bending moment

M = 5 × 10^3 × 2.5 = 12500 Nm

Maximum shear stress

$$\tau = \frac{16T}{\pi d^3} = \frac{16\times 2.5\times10^3}{\pi\times(0.1)^3}$$

= 12732395 N/m^2 = 12.73 MPa

Maximum bending stress

$$\sigma_b = \frac{32M}{\pi d^3} = \frac{32\times12500}{\pi\times(0.1)^3}$$

= 127323954 N/m^2

= 127.32 MPa

Major principal stress

$$\sigma_1 = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$$

$$= \frac{127.32}{2} + \sqrt{\left(\frac{127.32}{2}\right)^2 + (12.73)^2}$$

$$= 128.58 \text{ MPa}$$

Minor principal stress

$$\sigma_2 = \frac{127.32}{2} - \sqrt{\left(\frac{127.32}{2}\right)^2 + (12.73)^2}$$

$= -1.26$ MPa

According to Tresca's theory of failure

$$\frac{S_{sy}}{FS} = \frac{S_{yt}}{2 \times FS} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\therefore \frac{425}{FS} = \frac{128.58 + 1.26}{2}$$

FS = 3.27

11. **Ans: (a)**

Sol: $S_{yt} = 200$ N/mm^2

FS = 2.5

$$\frac{d}{b} = 2$$

$$\frac{S_{yt}}{FS} = \sigma_b = \frac{200}{2.5} = 80 \text{ MPa}$$

$$I = \frac{bd^3}{12} = \frac{b(2b)^3}{12} = 0.66b^4$$

Maximum Bending moment,

$$M = 5 \times 1500 + 5 \times 500$$

$$= 10000 \times 10^3 \text{N-mm}$$

$$80 = \frac{M}{I} \times y = \frac{10^7}{0.66b^4} \times \frac{d}{2}$$

$$80 = \frac{10^7}{0.66b^4} \times \frac{2b}{2}$$

$\Rightarrow b = 57.42$ mm

12. **Ans: (b)**

Sol: $\sigma_x = 100$ MPa , $\sigma_y = 40$ MPa, $\tau = 40$ MPa

$$\sigma = \frac{100 + 40}{2} \pm \sqrt{\left(\frac{100 - 40}{2}\right)^2 + 40^2}$$

$$\sigma_1 = 70 + \sqrt{30^2 + 40^2} = 120 \text{ MPa}$$

$$\sigma_2 = 70 - \sqrt{30^2 + 40^2} = 20 \text{ MPa}$$

According Distortion Energy Theory

$$\sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2} = \frac{S_{yt}}{FS}$$

$$\sqrt{120^2 + 20^2 - 120 \times 20} = \frac{360}{FS} \Rightarrow FS = 3.23$$

13. **Ans: (b)**

Sol: T = 10 kN-m , M = 10 kN-m

Equivalent torque, $T_e = \sqrt{10^2 + 10^2}$

$= 14.14$ kN-m

$$\tau_{max} = \frac{16T_e}{\pi d^3} = \frac{16 \times 14.14}{\pi d^3}$$

According to Maximum shear stress theory

$$\tau_{max} = \frac{S_{sy}}{FS}$$

$$\frac{16 \times 14.14}{\pi d^3} = \frac{S_{sy}}{1.5}$$

$$S_{sy} = \frac{16 \times 14.14 \times 1.5}{\pi d^3} = \frac{108.02}{d^3}$$

For M = 5 kN-m and T = 6 kN-m

$$T_e = \sqrt{5^2 + 6^2} = 7.81 \text{ kN-m}$$

$\tau_{max} \times FS$ = constant

$$= \frac{16 \times 7.81 \times FS}{\pi d^3} = \frac{16 \times 14.14 \times 1.5}{\pi d^3}$$

FS = 2.7

Chapter- 3
Fluctuating Loads

01. **Ans: (c)**

Sol: Given:

$b = 50mm$, $d = 10mm$

$t = 10mm$, $\sigma = 62.5$ MPa

Area, $A = (b-d)t$

$= (50 - 10)10 = 400mm^2$

$\sigma_{max} = \frac{F}{A}$

$F = \sigma_{max} \times A$

$= 62.5 \times 400 = 25000$ N

$F = 25$ kN

02. **Ans: (b)**

Sol: Given:

$S_u = 440$ MPa $q = 0.8$

$K_a = 0.67$ $K_b = 0.85$

$K_c = 0.9$ $K_d = 0.897$

$K_t = 2.37$ F.S = 1.5

Goodman's equation

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{F.S}$$

S_e' = Endurance strength of standard specimen under ideal conditions.

S_e = Modified endurance strength

$S_e = K_a K_b K_c K_d S_e'$

$S_e' = 0.5 S_{ut}$

$= 0.5\times440 = 220MPa$

$S_e = 0.67\times0.85\times0.9\times0.897\times K_e \times S_e'$

K_f = Actual stress concentration modifying factor

$K_f = 1 + q(K_t -1)$

$= 1 + 0.8(1.37) = 2.096$

K_e = Stress concentration modifying factor

$$= \frac{1}{K_f} = \frac{1}{2.096} = 0.48$$

$\therefore S_e = 48.63MPa$

For completely reverse load

$\sigma_m = 0$

$$\sigma_a = \frac{16\times10^3}{(50-10)t}$$

$$\therefore \sigma_a = \frac{400}{t} \text{ N/mm}^2$$

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{F.S} \quad \left(\text{Here} \frac{\sigma_m}{S_{ut}} = 0\right)$$

$$\sigma_a = \frac{S_e}{F.S} = \frac{48.63}{1.5} = \frac{400}{t}$$

$\therefore t = 12.3mm$

$t = 12mm$

03. **Ans: (b)**

Sol: $F = 50$ kN, $S_{ut} = 300$ MN/m^2

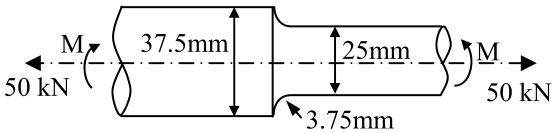
$S_e' = 200$ MN/m^2 , $K_t = 1.55$, $q = 0.9$

$M = ?$

$K_f = 1 + q(K_t - 1)$

$= 1 + 0.9(1.55 - 1) = 1.495$

$$S_e = \frac{1}{K_f}S_e' = \frac{200}{1.495} = 133.779$$



Mean stress, $\sigma_m = \dfrac{F}{A}$

$$= \frac{F}{\frac{\pi}{4}d^2} = \frac{50\times10^3}{\frac{\pi}{4}(25)^2} \Rightarrow 101.85 \text{ MPa}$$

Stress amplitude, $\sigma_a = \dfrac{32\,M}{\pi d^3} = \dfrac{32\,M}{\pi(25)^3}$

According to Goodman's equation

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{FS}$$

$$\underbrace{\frac{32M}{\pi(25)^3}}_{133.779} + \frac{101.85}{300} = 1$$

$\Rightarrow$ M = 135.5 N-m

04. **Ans: (b)**

Sol: Given:

$\sigma_1 = -50$MPa to +150MPa

$\sigma_2 = 25$MPa to 175MPa

$S_{ut} = 500$MPa , $S_e = 250$MPa

$K_t = 1.85$

$\sigma_{1max} = 150$ MPa, $\sigma_{1min} = -50$MPa

$$\sigma_{1mean} = \frac{\sigma_{1max} + \sigma_{1min}}{2}$$

$$= \frac{150-50}{2} = 50 \text{ MPa}$$

$$\sigma_{1a} = \frac{150+50}{2} = 100\text{MPa}$$

Similarly

$\sigma_{2\,max} = 175$MPa, $\sigma_{2\,min} = 25$MPa

$$\sigma_{2m} = \frac{175+25}{2} = 100\text{MPa}$$

$$\sigma_{2a} = \frac{150}{2} = 75\text{MPa}$$

According to Soderberg's equation

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{F.S}$$

Here,

$S_e = K_a K_b \ldots S_e'$

$$= \frac{1}{1.85}\times 250 = 135 \text{ N/mm}^2$$

According DET

$$\sigma_{meq} \leftarrow \left(\frac{S_{yt}}{F.S}\right) = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}$$

$$\therefore\ \sigma_{meq} = \sqrt{\sigma_{1m}^2 + \sigma_{2m}^2 - \sigma_{1m}\sigma_{2m}}$$

$= 86.6$MPa

$$\sigma_{aeq} = \sqrt{\sigma_{1a}^2 + \sigma_{2a}^2 - \sigma_{1a}\sigma_{2a}}$$

$= 90.14$MPa

Substituting these values in Soderberg's equation

$$\frac{90.14}{135} + \frac{86.6}{500} = \frac{1}{F.S}$$

F.S = 1.2

05. **Ans: (c)**

06. **Ans: (a)**

Sol: $S_e = 280$ MPa

$S_f = 0.9$ Sut for 10^3 Cycles

$S_u = 600$ MPa

$N = 10^3$ cycles $\quad S_f = ?$

Basquin's equation,

$A = S_f L^B$

$A = 280(10^6)^B$ ……… (1)

$A = (0.9\times600)\times10^{3B}$

$A = 540 \times 10^{3B}$……… (2)

By solving

$A = 1041.42$

$B = 0.095$

$\Rightarrow 1041.42 = S_f L^{0.095}$

$1041.42 = S_f (200\times10^3)^{0.095}$

$S_f = 326$ MPa

$\Rightarrow 1041.42 = 420 \times L^{0.095}$

$L = 1.4 \times10^4$ cycles

07. **Ans: (d)**

Sol: $S_{f1} = 500$ MPa $\quad N_1 = 10$ cycles

$L_1 = 1 \times 10^5$ cycles

$S_{f2} = 600$ MPa, $\quad N_2 = 5$ cycles

$L_2 = 0.4 \times10^5$ cycles

$S_{f3} = 700$ MPa, $\quad N_3 = 3$ cycles

$L_3 = 0.15 \times 10^5$ cycles

$$\frac{\alpha_1}{L_1}+\frac{\alpha_2}{L_2}+\frac{\alpha_3}{L}=\frac{1}{L}$$

$$\alpha_1 = \frac{N_1}{N_1+N_2+N_3} = \frac{10}{18}$$

$$\frac{10}{18(1\times10^5)}+\frac{5}{18(0.4\times10^5)}+\frac{3}{18(0.15\times10^5)}=\frac{1}{L}$$

$L = 42352.94$ Cycles

For $\quad$ 18 cycles $\rightarrow \frac{1}{2}\times 60$

42352.94 cycles $\rightarrow$? L

$\Rightarrow L = 19.6$ hrs

08. **Ans: (a)**

Sol: $d = 50$ mm

$T_{max} = 2$ kN-m

$T_{min} = -0.8$ kN-m

$S_{sy} = 225$ MPa,

FS = ? (Soderberg)

$S_{se} = 150$ MPa

$$T_a = \frac{2-(-0.8)}{2} = 1.4\,\text{kN}-\text{m}$$

$$T_m = \frac{2-0.8}{2} = 0.6\,\text{kN}-\text{m}$$

$$\tau_m = \frac{16T_m}{\pi d^3} = \frac{16\times0.6\times10^6}{\pi(50)^3} = 24.446\,\text{MPa}$$

$$\tau_a = \frac{16T_a}{\pi d^3} = \frac{16(1.4)\times10^6}{\pi(50)^3} = 57.04\,\text{MPa}$$

$$\frac{\sigma_a}{S_e}+\frac{\sigma_m}{S_{yt}}=\frac{1}{FS}$$

$$\frac{\tau_a}{S_{se}}+\frac{\tau_m}{S_{sy}}=\frac{1}{FS}$$

$$\frac{24.446}{225}+\frac{57.04}{150}=\frac{1}{FS}$$

FS = 2.04

09. **Ans: (c)**

Sol: $L_1 = 10$ hours

$N_1 = 9.8$ hours

$N_2 = 8.2$ hours

$L_2 = ?$

According to Minor's Equation

$$\frac{N_1}{L_1} + \frac{N_2}{L_2} = 1$$

$$\Rightarrow \frac{9.8}{10} + \frac{8.2}{L_2} = 1$$

$$L_2 = 410 \text{ hours}$$

Common Data for Questions 10 & 11

10. **Ans: (c)**

11. **Ans: (d)**

Sol: $\sigma_{max} = +\,130$ MPa

$\sigma_{min} = -130$ MPa

$$K_d = \frac{1}{K_f} = \frac{1}{1 + 0.95(1.85 - 1)}$$

$$S_e = K_a ...... S_e^{'}$$

$$= 0.76 \times 0.85 \times 0.897 \times \frac{1}{1 + 0.95(1.85 - 1)}(0.5 \times 1400)$$

$= 224.411$ MPa

$\therefore$ For a completely reversed,

$\sigma_m = 0$ $\quad\quad$ $\sigma_a = 130$ MPa

$$\tau_m = \frac{57 + 16}{2} = 36.5\,\text{MPa}$$

$$\tau_a = \frac{57 - 16}{2} = 20.5\,\text{MPa}$$

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

$$\sigma_{meq} = \sqrt{\sigma_m^2 + 3\tau_m^2} = \sqrt{3 \times 36.5^2}$$

$$= 63.21\,\text{MPa}$$

$$\sigma_{aeq} = \sqrt{\sigma_a^2 + 3\tau_a^2} = \sqrt{130^2 + 3(20.5)^2}$$

$$= 134.76 \text{ MPa}$$

According to Goodman's equation,

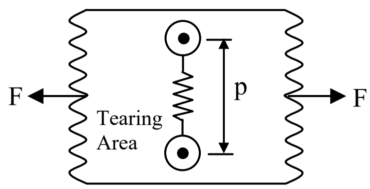
$$\frac{\sigma_{aeq}}{S_e} + \frac{\sigma_{meq}}{S_{ut}} = \frac{1}{Fs}$$

$$\frac{134.76}{224.4} + \frac{63.21}{1400} = \frac{1}{FS} \Rightarrow FS = 1.54$$

Chapter- 4
Riveted Joints

01. **Ans: (b)**

Sol: Given $\frac{d}{p} = 0.5$



Tearing efficiency $= \frac{p-d}{p}$

$$= \frac{p\left(1-\frac{d}{p}\right)}{p}$$

$$= 1-\frac{d}{p} = 1-0.5$$

$$= 0.5 \times 100 = 50\%$$

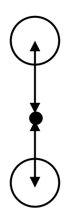
02. **Ans: (d)**

Sol: Resultant Force $= \sqrt{F_1^2 + F_2^2}$

$$= \sqrt{4^2+3^2}$$

$$= 5 \text{ kN}$$

$$F_1 = F_2 = \frac{F}{2} \Rightarrow F = 2F_2 = 2\times3 = 6 \text{ kN}$$



Stress $= \frac{F}{2} = \frac{5000}{500}$

$= 10$ MPa

$$C = \frac{F\times L}{r_1^2 + r_2^2}$$

As r_1 and r_2 not given, so it is not possible to calculate eccentricity (L).

Common Data Question (03, 04, 05)

Given $d = 30$ mm

$\sigma_t = 40\text{MPa} = 40\text{N/mm}^2$

$P = 90$mm

$\sigma_s = 30\text{MPa} = 30 \text{ N/mm}^2$

$t = 12.5$ mm

$\sigma_c = 55\text{MPa} = 55\text{N/mm}^2$

03. **Ans: (b)**

Sol: Tearing Efficiency $= \frac{p-d}{p}$

$$= \frac{90-30}{90} = \frac{60}{90}$$

$$= \frac{2}{3}\times100$$

$$\eta_{Tearing} = 66.67\%$$

04. **Ans: (b)**

Sol: Strength of Riveted plate $= P = p\times t\times\sigma_t$

$P = 90 \times 12.5 \times 40$

$= 45000$ N

Shearing Resistance,

$$P_S = \frac{\pi}{4}d^2 \times \sigma_t$$

$$P_s = \frac{\pi}{4}(30)^2 \times 30$$

$= 21206$N

Shear efficiency $= \frac{P_S}{P} = \frac{21206}{45000}$

$= 0.47 = 47\%$

05. **Ans: (c)**

Sol: Crushing Strength

$P_C = d \times t \times \sigma_c$

$= 30 \times 12.5 \times 55$

$= 20625$ N

Tearing Strength

$P_t = (p - d)t \times \sigma_t$

$= (90 - 30)\ 12.5 \times 40 = 30{,}000$ N

Shear Strength

$P_S = 21206$ N , $P = 45000$ N

Strength of riveted joint

$$\eta = \frac{\text{Least value among } P_C, P_t \ \& \ P_S}{P}$$

$$\eta = \frac{20625}{45000} = 0.458 = 45.8\%$$

06. **Ans: (c)**

Sol: Given t = 7mm

$\tau_s = 60\text{MPa} = 60\text{N/mm}^2$

$\sigma_c = 120\text{ MPa} = 120\text{N/mm}^2$

n = 3 (Triple riveted joint)

$$P_S = n \times \frac{\pi}{4} \times d^2 \times \tau_s$$

$$= 3 \times \frac{\pi}{4} d^2 \times 60 = 141.4 d^2 \text{ N} \ldots\ldots(1)$$

$P_C = n \times d \times t \times \sigma_c = 3 \times d \times 7 \times 120$

$= 2520d$ N …….. (2)

From equations (1) & (2)

$141.4\ d^2 = 2520d$

$$d = \frac{2520}{141.4} = 17.8 \approx 18\text{mm}$$

07. **Ans: (d)**

Sol: Given:

t = 7mm,

n = 3

$\sigma_t = 80\text{MPa} = 80\text{N/mm}^2$

$\tau_s = 60\text{ MPa} = 60\text{N/mm}^2$

$\sigma_c = 120\text{ MPa} = 120\text{N/mm}^2$

Let p = pitch of rivets,

d = 18mm

Tearing resistance is

$P_t = (p - d)t \times \sigma_t$

$= (p - 18)7 \times 80$

$= 560(p - 18)$ N ……. (1)

$$P_s = \frac{\pi}{4} d^2 \times \tau_s \times \eta$$

$$\frac{\pi}{4}(18)^2 \times 60 \times 3 = 45804 \text{ N} \ldots\ldots.. (2)$$

From equations (1) and (2)

$560(p-18) = 45804$

p = 99.79

p ≅ 100 mm

08. **Ans (a)**

Sol: $\dfrac{S_{yt}}{FS} = 90\text{ N/mm}^2$

$\dfrac{S_{sy}}{FS} = 75\text{ N/mm}^2$

$\dfrac{S_{yc}}{FS} = 150\text{ N/mm}^2$

Shear strength = crushing strength

$$\frac{\pi}{4}d^2 \times \frac{S_{sy}}{FS} = d \times t \times \frac{S_{yc}}{FS}$$

$$d = 6 \times \frac{150}{75 \times \pi} \times 4$$

d = 15.27 mm.

09. **Ans: (b)**

Sol: Given:

$\tau_s = 100MPa = 100N/mm^2$

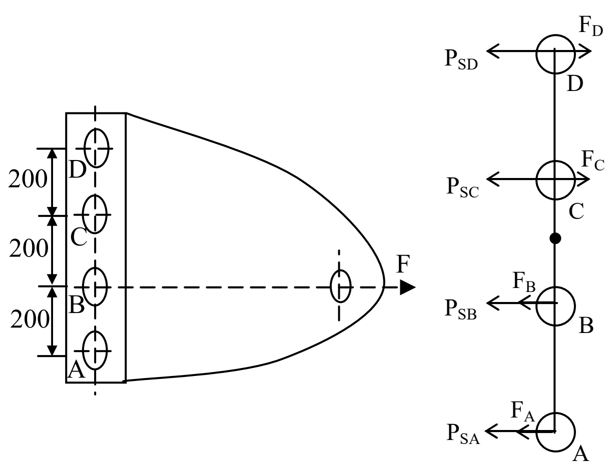
d = 20 mm, n = 4

Direct shear load on each rivet

$$P_S = \frac{P}{n} = \frac{P}{4} = 0.25P$$

$P_A = P_B = P_C = P_D = P_S$

All dimensions are in mm



From fig

$l_A = l_D = 200 + 100 = 300$ mm

$l_B = l_C = 100$ mm

[$\because$ Secondary shear loads are proportional to their radial distances from the C.G]

$$P \times e = \frac{F_B}{l_B}\left[l_A^2 + l_B^2 + l_c^2 + l_D^2\right]$$

$$= \frac{F_B}{l_B}\left[2l_A^2 + 2l_B^2\right] \quad (\because l_A = l_D \;\&\; l_B = l_c)$$

$$P \times 100 = \frac{F}{100}\left[2(300)^2 + 2(100)^2\right]$$

$$F_B = 0.05\,P = F_C$$

$$P \times e = \frac{F_A}{l_A}\left[l_A^2 + l_B^2 + l_c^2 + l_D^2\right]$$

$F_A = F_B = 0.15$ P

Resultant load on rivet A

$R_A = P_s + F_A = 0.25P + 0.15P = 0.4P$

Resultant load on rivet B,

$R_B = P_S + F_B = 0.25P + 0.05P$

$= 0.3P$

Resultant load on rivet C,

$R_C = P_S - F_C = 0.25P - 0.05P = 0.2P$

Resultant load on rivet D,

$R_D = P_S - F_D = 0.25P - 0.15P = 0.1P$

R_A is the maximum shear load

$$0.40P = \frac{\pi}{4}d^2 \times \sigma_s$$

$$0.4P = \frac{\pi}{4}(20)^2 100 = 31420$$

$$P = \frac{31420}{0.4} = 78.55\,kN \approx 78\,kN$$

10. **Ans: (b)**

Sol: Tensile load (F_t)

$= (p - d)t \times \sigma_t$

$= (60–20) \times 15 \times 120 = 72000N$

$= 72$ kN

Shear Load (F_s) = $\frac{\pi}{4} \times d^2 \times \tau = \frac{\pi}{4} \times 20^2 \times 90$

$= 28274.33$ N $= 28.274$ kN

Crushing load (F_c) = $d \times t \times \sigma_c$

$= 20 \times 15 \times 160$

$= 48000$ N $= 48$ Kn

Load carrying capacity (F)

= Minimum of (F_t,F_s& F_c)

$= 28.274$ kN

Linked Answer Questions 11 & 12:

11. **Ans: (a)**

Sol: No. of Rivets = 2

Primary shear load $P_1 = \frac{4}{2} = 2$ kN

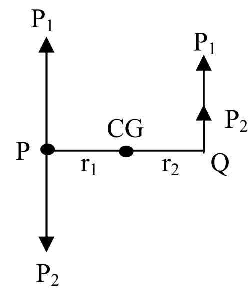
Secondary shear load $P_2 = \frac{Per_1}{r_1^2 + r_2^2}$

$= \frac{4\times10^3 \times (1.8 + 0.2) \times 0.2}{0.2^2 + 0.2^2}$

$= 20000$ N $= 20$ kN

12. **Ans: (b)**

Sol:



Resultant load on Rivet P = $P_2 - P_1$

$= 18$ kN

Resultant shear stress on Rivet P

$= \frac{18\times10^3}{\frac{\pi}{4}\times12^2} = 159$ MPa

Chapter- 5
Threaded Fasteners

01. **Ans: (b)**

Sol: Given d = 24 mm

$F_i = 2840d = 2840\times24$

$$\sigma_t = \frac{F_i}{\frac{\pi}{4}d_c^2}$$

Here, $d_c = 0.84d \Rightarrow d_c = 0.84 \times 24$

$$\sigma_t = \frac{2840\times24}{\frac{\pi}{4}(0.84\times24)^2}$$

$$\sigma_t = 213.529\,\text{MPa}$$

02. **Ans: (c)**

Sol: Given

d = 36mm

$d_c = 0.84\ d = 0.84\times36$

F.S = 1.5

S_{yt} = 280MPa

$$\sigma_t = \frac{s_{yt}}{F.s} = \frac{280}{1.5}$$

$$P = \frac{\pi}{4}d_c^2\,\sigma_t$$

$$= \frac{\pi}{4}(0.84\times36)^2\times\frac{280}{1.5}$$

= 134066 N

P = 134 kN

03. **Ans: (d)**

Sol: Given pitch = 4mm

Torque (T) = 1.4 kN-mm

Work done = force ×distance

Force×distance = Torque × Angle of rotation

F×4 = T×θ

$$F = \frac{1.4\times2\pi}{4} = 2.199\text{ kN} = 2.2\text{ kN}$$

04. **Ans: (d)**

Sol: Given

F = 5.3 kN , C = 0.25 , P = 9.6 kN

$F_b = CP + F_i$

= (0.25) (9.6) + (5.3)

F_b = 7.7 kN

05. **Ans: (c)**

Sol: $K_m = 4K_b$

$$C = \frac{K_b}{K_b + K_m} = 0.2$$

To open the joint

$(1-C)P = F_i$

$$\frac{P}{F_i} = \frac{1}{1-C} = \frac{1}{1-0.2} = 1.25$$

06. **Ans: (b)**

Sol: Given

D = 250mm

Pressure = 12bar = 1.2 MPa

F.S = 5

S_{yt} = 300MPa

n = 8

F_b = Load (P) = $\frac{\pi}{4}(D^2) \times P$

$$= \frac{\frac{\pi}{4}(250)^2 \times 1.2}{n} = 7363.1 \text{ N}$$

$$\sigma_t = \frac{F_b}{A_b} = \frac{S_{yt}}{F.S}$$

$$\Rightarrow \frac{7.36\times10^3}{A_b} = \frac{300}{5}$$

$\Rightarrow A_b = 122.66 \text{ mm}^2$

07. **Ans: (d)**

Sol: Given,

D = 500mm

n = 8

P = 20 bar = 2 MPa

$K_m = 3K_b$

$$c = \frac{K_b}{K_b + K_m} = \frac{1}{4} = 0.25$$

To avoid leakage

Load (P) = Pr ×A

$$= \frac{2\times\frac{\pi}{4}(500)^2}{8} = 49 \text{ kN}$$

For leak proof joint $F_m \le 0$

$F_i = (1- C)\ P$

$F_i = (1- 0.25)\ 49 = 36.75 \text{ kN} \approx 37 \text{ N}$

Linked Answer Q 08 & 09

08. **Ans: (d)**

Sol: S_{yt} = 650 MPa

A = 115 mm^2

$K_m = 1.7\times10^6$ N/mm ,

$E_{cu} = 1.05\times10^5$ N/mm^2

$E_{steel} = 2\times10^5$ N/mm^2

$F_i = 0.8S_{yt}\times A = 0.8 \times 650 \times 115 = 59800$ N

For bolt,

$$K_b = \frac{P_b}{\delta_b} = \frac{P_b}{\frac{P_b.l_b}{A_bE_b}} = \frac{A_bE_b}{l_b}$$

$$= \frac{115\times2\times10^5}{20+20} = 5.75\times10^5 \text{ N/mm}$$

Where, $l_b = t_1 + t_2 = 20 + 20 = 40$ mm

$$\text{Stiffness factor } C = \frac{K_b}{K_b + K_m} = 0.25$$

09. **Ans: (a)**

Sol: Safe external load that can be applied safely on the joint

$(1-C)P - F_i = 0$

$(1- 0.25)\times P = 59800$ N

P = 79733 N = 79.733 kN

For strength

$$\sigma_t = \frac{F_b}{A} = \frac{S_{yt}}{FS}$$

$$\Rightarrow F_b = \frac{S_{yt}\times A_b}{FS}$$

$$CP + F_i = \frac{S_{yt}\times A_b}{FS}$$

$$CP = \frac{S_{yt}}{FS} \times A_b - F_i$$

$$CP = \frac{650}{1} \times 115 - 59800$$

CP = 14950

$$P = \frac{14950}{0.25} = 59800\,N = 59.8\text{ kN} \cong 60\text{ kN}$$

Linked Answer Q 10 & 11

10. **Ans: (b)**

11. **Ans: (a)**

Sol: Given

$d = 20mm$, $S_{yt} = 630MPa$

$S_e = 350MPa$, F.S = 2.5

Core area of bolt = $2.45cm^2 = 245mm^2$

$\sigma_m = 180MPa$

Soderberg's criterion

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{yt}} = \frac{1}{F.s}$$

$$\frac{\sigma_a}{350} + \frac{180}{630} = \frac{1}{2.5}$$

$$\frac{\sigma_a}{350} = \frac{1}{2.5} - \frac{180}{630}$$

$\sigma_a = 40MPa$

For calculating maximum & minimum values of varying loads.

$\sigma_{max} = \sigma_{mean} + \sigma_a = 180 + 40 = 220\,MPa$

$P_{max} = \sigma_{max} \times Area = 220 \times 245 = 54$ kN

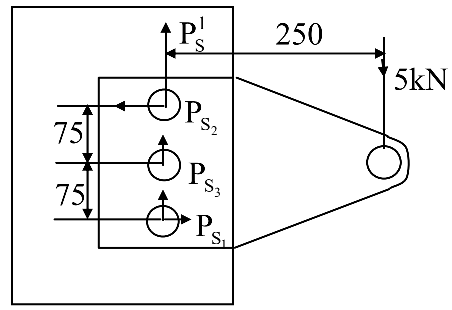
$\sigma_{min} = \sigma_{mean} - \sigma_a = 180 - 40 = 140\,MPa$

$P_{min} = \sigma_{min} \times Area = 140 \times 245 = 34$ kN

12. **Ans: (b)**

Sol: F.S = 3 , $S_{yt} = 400\ N/mm^2$, P = 5 kN

Direct shear load



$$P_s = \frac{5}{3} = 1.67\text{ kN}$$

Secondary shear Load, P_{S1}

$$= \frac{5 \times 250}{(75)^2 + 0^2 + (75)^2} \times 75 = 8.3kN$$

Resultant Load (R) = $\sqrt{P_S^2 + P_{S_1}^2}$

$= \sqrt{(1.67)^2 + (8.3)^2}$

= 8.498 kN

$$R = \frac{\pi}{4} d^2 \times \frac{S_{sy}}{F.s} \quad [S_{yt} = 2 \times S_{sy}]$$

$$8.498 \times 10^3 = \frac{\pi}{4}\left(d^2\right) \times \frac{S_{yt}}{2 \times F.s}$$

$\therefore d = 12.74mm \approx 13mm$

13. **Ans: (a)**

Sol: n = 4

P = 10 kN

$S_{yt} = 400N/mm^2$

FS = 6

$d_c = 0.8d$

Using Rankine theory

$P_A = CL_2$ (tensile load)

$$= \frac{PL}{2\left(L_1^2 + L_2^2\right)} \times L_2$$

$$= \frac{10 \times 550}{2\left(75^2 + 325^2\right)} \times 325 = 8 \text{ kN}$$

$$P_{direct} = \frac{P}{4} = 2.5\,\text{kN} = P_A = P_B$$

Bolt 'A' is subjected to maximum load

Rankine Theory

$\therefore$ Total Tensile load on bolt $= P_A + P'_A$

$= 8 + 2.5 = 10.5\text{kN}$

$$\sigma_t = \frac{F}{\frac{\pi}{4}d_c^2} = \frac{S_{yt}}{FS}$$

$$\frac{10.5}{\frac{\pi}{4}d_c^2} = \frac{400}{6}$$

$d_c = 14.16$

$$d = \frac{d_c}{0.8} = 17.7 = 18\text{mm}$$

14. **Ans: (c)**

Sol: Given

$n = 4$, $P = 5$ kN

$S_{yt} = 380\text{N/mm}^2$

F.S = 5 , $d_c = 0.8d$

$P_{tA} = KL_2 =$ (Tensile)

$$= \frac{PL}{2\left(L_1^2 + L_2^2\right)} \times L_2$$

$$= \frac{5 \times 250}{2\left(75^2 + 375^2\right)} \times 375$$

$= 1.6$ kN

$$P_{shear} = \frac{P}{4} = \frac{5}{4} = 1.25 \text{ kN}$$

Direct shear load,

$$P_{SA} = P_{SB} = \frac{P}{4} = 1.25 \text{ kN}$$

Bolts at 'A' is under maximum bending

Rankine Theory

$$\tau = \frac{P_{SA}}{A} = \frac{1.25 \times 10^3}{A}$$

$$\Rightarrow A = \frac{\pi}{4}d_c^2$$

$$\sigma_t = \frac{P_{tA}}{A} = \frac{1.6 \times 10^3}{A}$$

$$\sigma_1 = \frac{\sigma_t}{2} + \sqrt{\left(\frac{\sigma_t}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_1 = \frac{1.6 \times 10^3}{2A} + \frac{1}{A}\sqrt{\left(\frac{1.6 \times 10^3}{2}\right)^2 + \left(1.25 \times 10^3\right)^2}$$

$$= \frac{2292.22}{A}\,\text{N/mm}^2$$

According to Rankine Theory

$$\sigma_1 = \frac{S_{yt}}{FS}$$

$$\Rightarrow \frac{2292.22}{A} = \frac{380}{5}$$

$$\Rightarrow A = 30.16 \text{ mm}^2 = \frac{\pi}{4} \times d_c^2$$

$\Rightarrow d_c = 6.196$ mm

$$\Rightarrow d = \frac{6.196}{0.8} = 7.745 \text{ mm}$$

15. **Ans: (a)**

Sol: Given

$K_m = 3K_b$

$P_{min} = 0$

$P_{max} = 5$ kN

$F_i = 4.5$ kN

M8 $\Rightarrow$ d = 8

$A = 36.6 mm^2$

$$\sigma_a = \frac{CP}{2A}$$

$$\text{Here, } C = \frac{K_b}{K_b + K_m}$$

$$= \frac{K_b}{K_b + 3K_b} = \frac{K_b}{4K_b} = 0.25$$

$$\Rightarrow \sigma_a = \frac{0.25 \times 5 \times 10^3}{2 \times 36.6} = 17.07\text{MPa}$$

$\sigma_a = 17$MPa

$$\sigma_m = \sigma_a + \frac{F_i}{A}$$

$$= 17 + \frac{4.5 \times 10^3}{36.6}$$

$\sigma_m = 140$MPa

Chapter- 6
Welded Joints

01. **Ans (b)**

Sol: Given: $s = 10$ mm ,

$\tau = 80$ MPa

$P = 0.707 \times s \times l \times \tau$

$= 0.707 \times 10 \times 10 \times 80 = 5.6$kN

02. **Ans (c)**

Sol: Given , $P = 400$ kN ,

$\tau = 80$ MPa

$$P = 2 \times 0.707 \times s \times \ell \times \frac{S_{sy}}{FS}$$

$400 \times 1000 = 2 \times .707 \times 10 \times 80 \times l$

$$l = \frac{400000}{1.414 \times 10 \times 80}$$

$l = 354$ mm

The nearest answer is option (c)

03. **Ans: (b)**

Sol: $S = 10$ mm, $P = 4$ kN/cm

$$P_{transverse} = 0.707 \times S \times l \times \frac{S_{sy}}{FS}$$

4 kN $\rightarrow$ 1 cm

$$180 \text{ kN} = \frac{180}{4} = 45 \text{ cm} = 450 \text{ mm}$$

$\therefore l + 100 + l = 450$

$l = 175$ mm

04. **Ans (a)**

Sol: Given: d = 60mm , s =10mm,

τ = 70MPa

$$\tau = \frac{T}{J}\times r = \frac{T}{2\pi r^3 t}\times r = \frac{T}{2\pi r^2 t}$$

$$= \frac{T}{2\pi r^2 \times 0.707 s}$$

$$= \frac{T}{2\pi \times \frac{d^2}{4} \times 0.707 \times s}$$

$$\tau = \frac{2.83T}{\pi s d^2}$$

s = Size of the weld

$$T = \frac{70\times\pi\times10\times(60)^2}{2.83}$$

= 2797460 N-mm $\Rightarrow$ T = 2.797 kN-m

05. **Ans (a)**

Sol: t = 10 mm

d = 15 × 10^3 mm

$$\frac{S_{yt}}{FS} = 85 \text{ MPa}$$

$$\sigma_l = \sigma_h = \frac{pd}{4t} = \sigma_1$$

According to Rankine Theory

$$\sigma_1 = \frac{S_{yt}}{FS}$$

$$\frac{pd}{4t} = 85$$

$$\Rightarrow \frac{p\times15\times10^3}{4\times10} = 85$$

$\Rightarrow$ p = 0.226 MPa

06. **Ans: (a)**

Sol: Given:

P = 340kN = 340000N

$$\frac{S_{sy}}{FS} = 80\text{MPa},$$

s =15mm

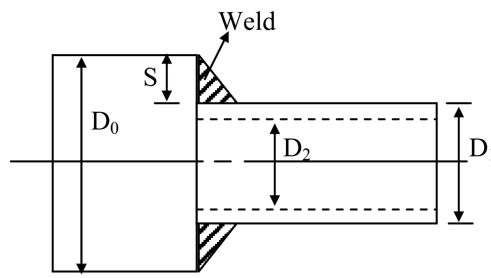
$$P = 0.707 s\, l \times \frac{S_{sy}}{FS}$$

$$340\times10^3 = 0.707\times15\times1\times80$$

l = 400 mm length of weld adjusted on both sides i.e., 200 mm on each side.

07. **Ans: (b)**

Sol:



D_1 = 205 mm, D_2 = 200 mm

D_0 = 210 mm,

$$\frac{S_{sy}}{FS} = 110 \text{ MPa}$$

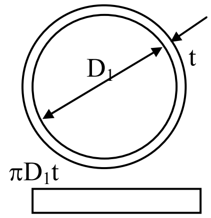
$$s = \frac{210-205}{2} = 2.5 \text{ mm}$$

t = 0.707 s = 0.707× 2.5 = 1.7675 mm

Force = Pressure × Area

$$= P \times \frac{\pi}{4}D_2^2 \text{ ………. (1)}$$

$$F = \pi D_1 t \times \frac{S_{sy}}{FS} \text{ ……….. (2)}$$



Equate (1) & (2)

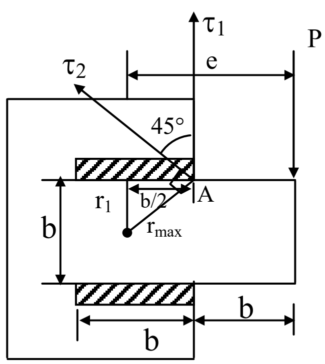
$$P \times \frac{\pi}{4} D_2^2 = \pi D_1 t \frac{S_{sy}}{FS}$$

$$P = \frac{205 \times 4 \times 1.7675}{(200)^2} \times 110$$

P = 3.9857 MPa

08. **Ans: (a)**

Sol:



Primary shear stress

$$\tau_1 = \frac{P}{b \times t \times 2}$$

Secondary shear stress

$$\tau_2 = \frac{T}{J} \times r_{max}$$

$$T = P \times e = P\left(b + \frac{b}{2}\right) = 1.5\ Pb$$

$$J = A\left(\frac{l^2}{12} + r_1^2\right) \times 2$$

$$A = b \times t$$

$$l = b$$

$$r_1 = \left(\frac{b}{2} + \frac{t}{2}\right)$$

$$= \frac{b}{2} \quad (\because b >> t)$$

r_1 = distance between two centroids.

r_{max} = distance from centroid to maximum distance on weld

$$\therefore\ J = b \times t\left[\frac{b^2}{12} + \frac{b^2}{4}\right] \times 2 = \frac{2b^3 t}{3}$$

$$r_{max} = \sqrt{\left(\frac{b}{2}\right)^2 + \left(\frac{b}{2}\right)^2} = \frac{b}{\sqrt{2}}$$

$$\tau_2 = \frac{T}{J} \times r_{max} = \left(\frac{1.5Pb}{\frac{2b^3 t}{3}}\right) \times \frac{b}{\sqrt{2}} = \frac{1.59P}{bt}$$

Resultant Shear stress

$$\tau = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2\cos\theta}$$

$$= \sqrt{\left(\frac{P}{bt \times 2}\right)^2 + \left(\frac{1.59P}{bt}\right)^2 + 2\left(\frac{P}{2bt}\right)\left(\frac{1.59P}{bt}\right)\cos 45}$$

θ = Angle between τ_1 and τ_2

$$= \frac{P}{bt}\sqrt{\left(\frac{1}{2}\right)^2 + (1.59)^2 + 2 \times \frac{1}{2} \times 1.59 \times \cos 45}$$

$$= \frac{1.975P}{bt}$$

09. **Ans: (a)**

Sol: Given: τ =140 MPa , s = 6 mm

d =50 mm , r = 25 mm

We know that

$$\tau = \frac{T}{2\pi r^2 t}$$

$\therefore\ T = 2\pi r^2 \times t \times \frac{S_{sy}}{FS}$

$= 2\pi \times 25^2 \times (0.707 \times 6) \times 140$

$\Rightarrow T = 2332161$ N-mm

$= 2332.161$ Nm

Linked questions (Q.10 &Q.11)

10. **Ans: (a)**

11. **Ans: (a)**

Sol: Given:

$\tau = 75 N/mm^2$, $s = 10$ mm

$P = 200$ kN , $a = 145$ mm

$P = 200 \times 10^3 N$

$b = 55mm$

$$P = \tau \times 0.707 s \times l$$

$$200 \times 10^3 = 75 \times 0.707 \times 10 \times \ell$$

$$l = \frac{200 \times 10^3}{75 \times 0.707(10)}$$

$$l = 377.18mm$$

$$l_a = \frac{l \times b}{a + b}$$

$$= \frac{377.18 \times 55}{(145 + 55)} = 103.72\,mm$$

For calculating force carried by top weld

$$P = \tau \times 0.707 \times s \times \ell_a$$

$$= 75 \times 0.707 \times 10 \times 103.7$$

$= 54986.9$ N

$= 54.9$ kN

$P = 55$ kN

Chapter- 7
Sliding Contact Bearings

01. **Ans: (b)**

Sol: Given:

Load $W = 3$ kN

$d = 40$ mm

$p = 1.3$ MPa $= 1.3$ N/mm^2

$$\text{Pressure } (p) = \frac{W}{l \times d}$$

$$l = \frac{W}{p \times d}$$

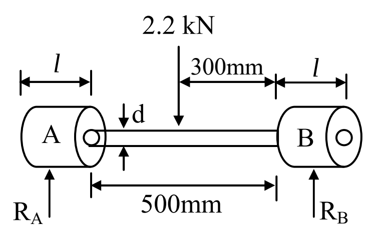
$$= \frac{3000}{1.3 \times 40}$$

$l = 57.69$ mm

$$\frac{\ell}{d} = \frac{57.69}{40} = 1.44 \approx 1.45$$

02. **Ans: (a)**

Sol:



$$\frac{\ell}{d} = 1.5$$

$d = 25$ mm $l = 500$ mm

$W = 2.2$ kN $a = 300$ mm

$P = ?$

$\Sigma M_B = 0$

$R_A \times 500 = 2.2 \times 300$

$R_A = 1.32$ kN

$R_B = 2.2$ kN $-1.32 = 0.88$ kN

Bearing pressure,

$$P = \frac{R_A}{\ell d} = \frac{1.32\times10^3}{25\times1.5\times25} = 1.408\,\text{MPa}$$

03. **Ans: (a)**

Sol: Given:

$d = 75$ mm , $N_1 = 300$ rpm

$p_1 = 1.4$ MPa $= 1.4$ N/m^2

$\mu = 0.06$ Pa – sec , $N_2 = 400$ rpm

$p_2 = ?$

$$\frac{\mu_1 N_1}{p_1} = \frac{\mu_2 N_2}{p_2}$$

Since, same oil is used μ is same I . e. $\mu_1 = \mu_2$

$$\Rightarrow \frac{N_1}{p_1} = \frac{N_2}{p_2}$$

$$\frac{300}{1.4} = \frac{400}{p_2}$$

$$p_2 = \frac{400\times1.4}{300}$$

$p_2 = 1.87$ MPa

04. **Ans: (b)**

Sol: Given: Eccentricity ratio, $\varepsilon = 0.8$

$$\varepsilon = 1 - \frac{h_0}{C}$$

$$\frac{h_0}{C} = 1 - 0.8$$

$$\frac{h_0}{C} = 0.2$$

05. **Ans: (a)**

Sol: $d = 150$ mm $= 0.15$ m

$L = 225$ mm $= 0.225$ mm

Load (W) = 9kN = 9000 N

$C = 0.075$ mm,

Diametral clearance

$(C_d) = 2 \times 0.075 = 0.15$ mm

$= 0.15 \times 10^{-3}$ m

$N = 1000$ rpm

Heat dissipated by bearing =90 kJ/min

$$H = \frac{90}{60}\ \text{kW} = 1.5\ \text{kW}$$

Heat generated at the bearing = 1500 W

$$V = \frac{\pi d N}{60} = \frac{\pi\times0.15\times1000}{60}$$

$V = 7.85$ m/sec,

f = coefficient of friction

Load (W) = 9000N

Heat generated = f .V.W

$1500 = f\,(7.85)\,(9000)$

$$f = \frac{1500}{7.85\times9000} = 0.021$$

$$\frac{d}{c_d} = \frac{150}{2\times0.075} = 1000$$

$$\text{Pressure (p)} = \frac{\text{Load}}{l\times d}$$

$$p = \frac{9000}{0.15\times0.225} = 0.267\text{MPa}$$

According to Mckee equation

$$f = 0.326\left(\frac{\mu N}{p}\right)\left(\frac{d}{C_d}\right) + 0.002$$

$$0.0212 = 0.326\left(\frac{\mu\times1000}{0.267\times10^{6}}\right)1000 + 0.002$$

$\mu = 0.0157$ Pa – sec

06. **Ans: (a)**

Sol: Given:

d = 50 mm , l = 75 mm, f = 0.0015

p = 2MPa , N = 500 rpm

C = 11.6 W/m^{2o}C , $T_r = 28\ ^oC$

Heat lost in friction = f× W×V

$$= (f)\ (p\times l\times d)\left(\frac{\pi dN}{60}\right)$$

$$= 0.0015\times2\times50\times75\times\frac{\pi\times0.05\times500}{60}$$

= 14.72 Nm/sec

$14.72 = CA\ (T_s - T_r)$

$14.72 = 11.6\times0.05\times0.075\times8(T_s - 28)$

$T_s = 70.2^0C$

Linked Answer Question (7 & 8)

07. **Ans: (a)**

08. **Ans: (c)**

Sol: Given:

d = 100mm = 0.1m

l = 150 mm = 0.15 mm

W = 4.5 kN = 4500N

N = 600rpm

$\mu = 18.5\times10^{-3}$ kg/m–s = 0.0185 kg/m– s

$C_d = 0.1$

$\varepsilon = 0.4$

$$\text{Sommerfeld Number} = \left(\frac{\mu N_s}{p}\right)\left(\frac{d}{C_d}\right)^2$$

$$\text{Here pressure (p)} = \frac{W}{A} = \frac{W}{l\times d}$$

$$= \frac{4500}{0.15\times0.1} = 30\times10^4\ \text{N/m}^2$$

P = 0.3 MPa

Sommerfeld no "S"

$$= \frac{0.0185\times\left(\frac{600}{60}\right)}{0.3\times10^{6}}\left(\frac{100}{0.1}\right)^2$$

= 0.617

$$\text{Eccentricity ratio, } \varepsilon = 1 - \frac{h_0}{\left(\frac{C_d}{2}\right)}$$

$$0.4 = 1 - \frac{h_0}{\left(\frac{0.1}{2}\right)}$$

$h_0 = 0.03$ mm

09. **Ans: (a)**

Sol: Given

W = 150 kN , N = 1800 rpm

d = 300 mm = 0.3 m

p = 1.6N/mm^2 = 1.6 ×10^6 Pa

$C_d = 0.25$, $\mu = 20\times10^{-3}$ Pa-sec

K = 0.002

$$f = \left[0.326\left(\frac{\mu N}{p}\right)\left(\frac{d}{C_d}\right) + K\right]$$

$$= \left[0.326\left(\frac{20\times10^{-3}\times1800}{1.6\times10^{6}}\right)\left(\frac{300}{0.25}\right) + 0.002\right]$$

= 0.01

Heat generation = $0.01 \times 150 \times \pi \times d \times N$

$= 0.01 \times 150 \times \pi \times 0.3 \times 1800$

$= 2748.7$ kJ/min

10. **Ans: (a)**

Sol: Given:

$d_1 = 75$mm

$d_2 = 12$mm

$p = 0.6$ MPa $= 0.6$N/mm^2

$$\text{Area} = \frac{\pi}{4}\left(d_1^2 - d_2^2\right)$$

$$A = \frac{\pi}{4}\left(75^2 - 12^2\right)$$

$A = 4304.77$ mm^2

Axial load = $p \times A$

$= 0.6 \times 4304.77$ N

$= 2582.862$ N

$P = 2.58$ kN

11. **Ans: (a)**

Sol: d = 60 mm = 0.06 m

N = 600 rpm , P = 120 kPa

f = 0.05

For foot step bearing

$$T_f = \frac{2}{3}\mu \times F \times r$$

$$= \frac{2}{3} \times 0.05 \times 120 \times 10^3 \times \frac{\pi}{4} \times 0.06^2 \times 0.03$$

$T_f = 0.339$N-m

$$P = \frac{2\pi N T_f}{60}$$

$$= \frac{2\pi \times 600 \times 0.339}{60} = 21.29$$

P = 21.3W

Chapter- 8
Rolling Contact Bearings

01. **Ans: (d)**

Sol: 6205 bearing

C = 10.8 kN

6305 series bearing have higher load carrying capacity than 6205 bearing. Hence among the given option 16.2 kN is greater than 10.8kN.

02. **Ans: (b)**

Sol: Given: 6210 bearing

C = 22.5 kN

L = 27 million rev

6 – series – Ball bearing

$$L_{10} = \left(\frac{C}{P}\right)^3$$

K = 3 for Ball bearing

$$27 = \left(\frac{22.5}{P}\right)^3$$

$$P^3 = \frac{11.39 \times 10^3}{27}$$

P = 7.5 kN

03. **Ans: (b)**

Sol: Given: C = 48.545 kN

L = 6000 hrs

N = 500 rpm

$$L_{10} = \left(\frac{C}{P}\right)^K$$

For Ball bearing, K = 3

$$L_{10} = \left(\frac{48.545}{P}\right)^3$$

$$L_{10} = \frac{L_{50}}{5} = \left(\frac{48.545}{P}\right)^3$$

$$L_{50} = \frac{60NL_H}{10^6} = \frac{60\times500\times6000}{10^6}$$

= 180 million rev

$$L_{10} = \frac{L_{50}}{5} = \frac{180}{5} = \left(\frac{48.545}{P}\right)^3$$

$$36 = \left(\frac{48.545}{P}\right)^3$$

P = 14.7 kN

Linked Answer Question (04 & 05)

04. **Ans: (a)**

05. **Ans: (c)**

Sol: F_r = 2.5 kN

F_a = 1.5 kN

C_s = 1.5

N = 1000 rpm

X = 0.56

Y = 1.4, V = race rotation factor = 1

Equivalent load (P) = $(XVF_r + YF_a)C_s$

V for most bearings = 1

P = [(0.56 × 1 × 2.5) + (1.4 × 1.5)]1.5

P = [11.4 + 2.1]1.5

P = (3.5)(1.5)

P = 5.25 kN

$$L_{10} = \left(\frac{c}{P}\right)^K$$

K = 3 for ball bearing

$$L_H = \frac{40\,\text{hrs}}{\text{week}}\times\frac{52\,\text{weeks}}{\text{yr}}\times 5\,\text{years}$$

= 10,400 hrs

$$L = \frac{60\times N\times L_H}{10^6}$$

$$= \frac{60\times1000\times10{,}400}{10^6}$$

L = 624 million revolutions

$$L_{10} = \left(\frac{C}{P}\right)^3$$

$$624 = \left(\frac{C}{5.25}\right)^3$$

$$\frac{C}{5.25} = 8.545$$

C = 44.86 kN

Linked Answer Question (06 & 07)

06. **Ans: (c)**

07. **Ans: (a)**

Sol: Given C = 16.6 kN

% of element time = α

$$N_1 = \alpha_1 n_1 = \frac{30}{100}\times 900 = 270$$

$$N_2 = \alpha_2 n_2 = \frac{40}{100}\times 1440 = 576$$

$$N_3 = \alpha_3 n_3 = \frac{30}{100}\times 720 = 216$$

N = 270 + 576 + 216 = 1062

$$P = \left(\frac{N_1P_1^3 + N_2P_2^3 + N_2P_3^3}{N_1 + N_2 + N_3}\right)^{1/K}$$

K = 3 for Ball bearing

$$\left[\frac{(270\times 5^3)+(576\times 7^3)+(216\times 3^3)}{270+576+216}\right]^{1/3}$$

$$=\left[\frac{33750+197568+5832}{1062}\right]^{\frac{1}{3}}$$

$$=\left[\frac{237150}{1062}\right]^{1/3}$$

P = 6.067 kN

$$L=\left(\frac{C}{P}\right)^K$$

$$L=\left(\frac{16.6}{6.067}\right)^3$$

L = 20.5 million rev

Linked Answer Question (08 to 11)

08. **Ans: (b)**

09. **Ans: (a)**

10. **Ans: (b)**

11. **Ans: (a)**

Sol: Given:

$T_1 = 3$ kN

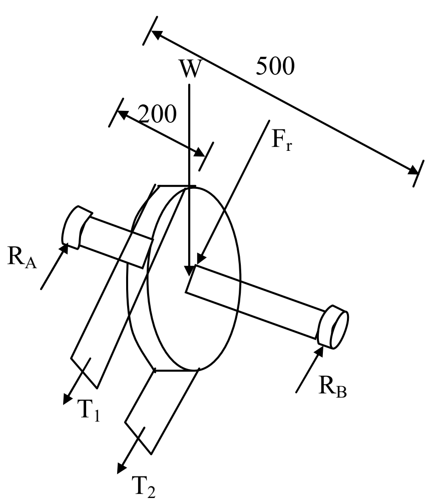
$T_2 = 1.5$ kN

$F_a = 2$kN

$L_H = 5000$ hrs

X = 0.56

Y = 1.5



W = weight of pulley = 1 kN

Resultant Radial load of shaft

$$=\sqrt{(3+1.5)^2+1^2}$$

$R = 4.61 \text{ kN} = R_A + R_B$

Take $\sum M_B = 0$

$R_A \times 500 = R \times 300$

$$R_A=\frac{4.61\times 300}{500}$$

$R_A = 2.766$ kN,

$R_B = 1.8436$ kN

Equivalent load

$P = [XVF_r + F_aY]$

$= (0.56 \times 1 \times 2.76) + (1.5 \times 2)$

$P = 4.546$ kN

Dynamic load rating

$$L_{10}=\left(\frac{C}{P}\right)^K, \quad [K = 3 \text{ For Ball bearing}]$$

$$L_{10}=\frac{60\times 400\times 5000}{10^6}=120 \text{ million rev}$$

$$120=\left(\frac{C}{4.55}\right)^3$$

C = 22.44kN

Chapter- 9
Clutch Design

01. **Ans: (b)**

Sol: Given,

$W = 1000N$, $n = 2$

$r_1 = 150mm = 0.15mm$

$r_2 = 100mm = 0.1mm$

$\mu = 0.5$

Mean Radius (R) $= \dfrac{r_1 + r_2}{2}$

$= \dfrac{150+100}{2}$

$R = 125mm$

Torque Transmitted,

$T = n\mu WR$

(For both sides effective n = 2)

$= 2 \times 0.5 \times 1000 \times 125$

$= 125000$ N–mm

$T = 125$ N–m

Linked Answer Questions (2 & 3)

02. **Ans: (a)**

03. **Ans: (a)**

Sol: $P = 10$ kW

$T = 100$ N-m

$n = 2$

$p_{max} = 0.085$ MPa

$d_1 = 1.25d_2$

$r_1 = 1.25r_2$

$\mu = 0.3$

$$T = \frac{\mu W(r_1 + r_2)}{2} \times n \quad \text{for uniform wear}$$

$$= \frac{\mu 2\pi C(r_1 - r_2)(r_1 + r_2)}{2} \times 2$$

$[\because W = 2\pi C(r_1 - r_2),\ C = p_1r_1 = p_2r_2]$

$100 = (0.3)2\pi(0.085)(r_2)(r_1^2 - r_2^2)$

$100\times10^3 = (0.3)2\pi(0.085)(r_2)[(1.25r_2)^2 - r_2^2]$

$r_1 = 130$ mm, $d_2 = 208$ mm

$r_2 = 104$ mm, $d_1 = 260$ mm

$W = 2\pi C(r_1 - r_2)$

$= 2\pi(p_{max})(r_2)(r_1 - r_2)$

$= 2\pi(0.085)(104)(130 - 104)$

$W = 1.44$ kN

04. **Ans: (b)**

Sol: $T_{max} = 140$ N-m

$d_1 = 220$ mm, $d_2 = 150$ mm

$P_{max} = 0.25$ MPa

$\mu = 0.3$

$$T = \mu W\left(\frac{r_1 + r_2}{2}\right)$$

$$= \mu(2\pi)C(r_1 - r_2)\left(\frac{r_1 + r_2}{2}\right)$$

$$= \mu\ 2\pi\ P_{max}\ r_2\left(\frac{r_1^2 - r_2^2}{2}\right)$$

i) $T_1 = 114$ N-m Slip takes place

ii) $T_2 = 148$ N-m suitable

iii) $T_3 = 173$ Nm

05. **Ans: (c)**

Sol: Given , $\mu = 0.5$

$r_1 = 150mm = 0.15m$

$r_2 = 100mm = 0.1m$

$T = 0.4$ kN–m = 400 N–m

$n_1 + n_2 = 5$,

n = No. of pairs of contact surface

$n = n_1 + n_2 - 1 = 5 - 1 = 4$

$$R = \frac{r_1 + r_2}{2} = \frac{0.15 + 0.1}{2} = 0.125m$$

$T = n\mu W R$

$400 = 4(0.5)(W)\,0.125$

$W = 1600$ N

∵ Four springs exert axial load,

$$\text{Load per spring} = \frac{1600}{4} = 400 \text{ N}$$

Linked Answer Question (06 & 07)

06. **Ans: (b)**

Sol: N = 1000 rpm,

$2\alpha = 24^0 \Rightarrow \alpha = 12^0$

$\mu = 0.2$, $r_m = 150$ mm, P = 20 kW

$p = 70$ kN/m^2

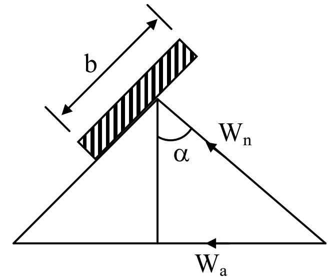
$$T = \frac{60P}{2\pi N} = \mu W_n r_m = \mu W_n \left(\frac{r_1 + r_2}{2}\right)$$

$$T = \frac{60(20)\times 1000}{2\pi(1000)} = 191 \text{ N-m}$$

191×10^3 N-mm $= 0.2 \times W_n \times 150$

$W_n = 6366.19$ N [$\therefore W_a = W_n \sin\alpha$]

$W_a = 1323.60$ N



Force required for engagement

$W_{ae} = W_a + \mu W_n \cos\alpha$

$= 1323.60 + [0.2 \times 6366.19 \times \cos 12]$

$W_{ae} = 2.56$ kN

07. **Ans: (b)**

Sol: $W_n = p \times 2\pi r_m \times b$

$6366.19 = 70 \times 10^3 \times 2 \times \pi \times 0.15 \times b$

$\Rightarrow$ b = 0.0964 m = 96.4 mm

Common Data for Q. 8 & 9

08. **Ans: (c)**

09. **Ans: (a)**

Sol: $N_1 = 200$ rpm,

$$\omega_1 = \frac{2\pi N}{60} = \frac{2\times\pi\times 200}{60} = 20.95 \text{ rad/s}$$

$\omega_2 = 0$

$$\alpha = \frac{\omega_1 - \omega_2}{t} = \frac{20.95}{5} = 4.18 \text{ rad/s}^2$$

Torque $T = I\alpha$

$= 20 \times 4.18 = 83.6$ N-m

$\mu = 0.3$

For uniform pressure,

$$T = \frac{2}{3}\mu W\left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]\times n$$

$$83.6\times10^3 = \frac{2}{3}\times0.3\times W\left[\frac{100^3-60^3}{100^2-60^2}\right]\times2$$

W = 1706.12 N

10. Ans: (a)

Sol: Given

D = 300mm

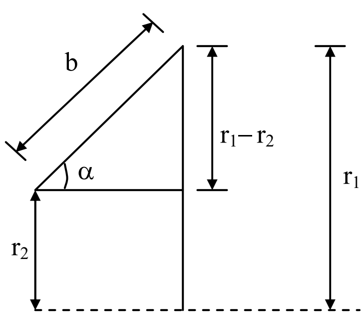
b = 100mm

$\mu = 0.2$

$\alpha = 10^0$

p = 0.07 MPa = 0.07 N/mm^2

N = 500 rpm



We know that

$W = 2\pi C(r_1 - r_2)$

$= 2\pi pr(r_1 - r_2)$ $(\because C = p\times r)$

$= 2\pi prb\sin\alpha$ $(r_1 - r_2 = b\sin\alpha)$

$= 2\pi\times0.07\times150\ (100\sin10^0)$

W =1146 N

$$W_n = \frac{W}{\sin\alpha} = \frac{1146}{\sin10}$$

W_n = 6599 N

Force required for engagement

$W_{en} = W_n(\sin\alpha + \mu\cos\alpha)$

$= 6599(\sin10 + 0.2\cos10)$

W_{en} = 2445 N

11. Ans: (d)

Sol: $T = \frac{60P}{2\pi N} = 318.3\ N-m$

$\omega_2 = \frac{2\pi N}{60} = 78.5$ rad/s

$318.3 = n\times\mu\times mr(\omega_2^2 - \omega_1^2)\times R$

$\omega_1 = 0.75\omega_2$, $n = 4$

$$318.3 = 4\times0.25\times m\times0.125\left(1-\frac{9}{16}\right)\times78.5^2\times0.15$$

m = 6.3kg

12. Ans: 157mm & 135.22mm

Sol: Centrifugal force between each shoe and drum

$F = mr(\omega_2^2 - \omega_1^2)$

F = 2123.08 N

$\text{Area} = \frac{F}{0.1} = 21230.87\ \text{mm}^2$

$\text{width}\times\text{arc length} = w\times\frac{\pi}{3}\times150 = 21230.87$

w = 135.22 mm

$\text{Length} = \frac{\pi}{3}\times150 = 157$ mm

Length = 157 mm

Width = 135.22 mm

Chapter- 10
Brakes

Linked Answer Questions (01 & 02)

01. **Ans: (b)**

Sol: $\Sigma M_{Pivot} = 0$

$300 \times 500 = R_N \times 200$

$R_N = 750$ N

$F_t = \mu R_N = 180$ N

$T = F_t\, r$

$= 180 \times \left(\frac{300}{2}\right) \times 10^{-3} = 27$ N-m

02. **Ans: (a)**

Sol: $\omega_1 = \frac{2\pi \times 100}{60} = 10.47$ rad/sec

$\omega_2 = 0$

Capacity to bring the system to rest from 100 rpm = work done = Heat generation = $T \times \theta$

$= T \times \left(\frac{\omega_1 + \omega_2}{2}\right) t$

$= 27 \times 5.235 \times 5 = 706.725$ J

03. **Ans: (b)**

Sol: $\mu = 0.3$

$2\theta = 90^0 = \pi/2$ rad

$\theta = 45^0$

Equivalent coefficient of friction

$$\mu^1 = \frac{4\mu \sin\theta}{2\theta + \sin 2\theta}$$

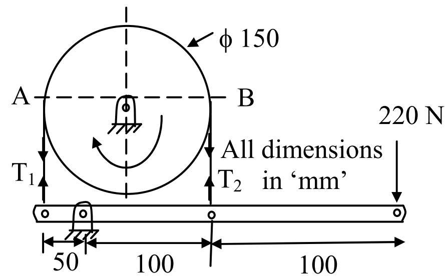
$$= \frac{4 \times 0.3 \times \sin 45^0}{\pi/2 + \sin 90^0}$$

$$= \frac{0.848}{2.57} = 0.329 = 0.33$$

Common Data Question (04 & 05)

04. **Ans: (c)**

Sol:



T = 450 N $\qquad \mu = ?$

P = 220 N – m $\qquad$ a = 50

b = 100

$\Sigma M_{pivot} = 0$

$(220 \times 200) - (T_2 \times 100) + (T_1 \times 50) = 0$

$T_2 \times 100 - 50 T_1 = 220 \times 200$ .... (1)

$T = (T_1 - T_2) \times r$

$T = (T_1 - T_2)\left(\frac{0.150}{2}\right)$

$T_1 - T_2 = 6000$ ...... (2)

From (1) and (2) $T_1 = 12880$ N

$T_2 = 6880$ N

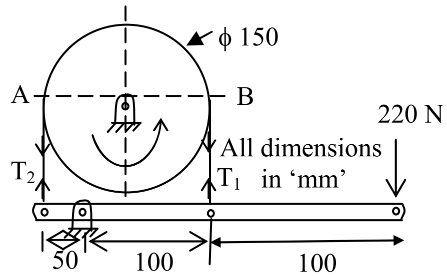
$$\frac{T_1}{T_2} = e^{\mu \times \theta}$$

$$\frac{12880}{6880} = e^{\mu \times \pi}$$

$\Rightarrow \mu = 0.199 = 0.2$

05. **Ans: (a)**

Sol:



We know that

$$ln\left(\frac{T_1}{T_2}\right) = \mu\ \theta$$

Here, $\mu = 0.4$, as given

$$ln\left(\frac{T_1}{T_2}\right) = 0.4 \times \pi$$

$$ln\left(\frac{T_1}{T_2}\right) = 0.546$$

(or)

$$\left(\frac{T_1}{T_2}\right) = e^{\mu\theta}$$

$$\left(\frac{T_1}{T_2}\right) = e^{(0.4 \times \pi)}$$

$$\left(\frac{T_1}{T_2}\right) = 3.51 \ldots\ldots. (1)$$

Here when the drum rotates in anti clockwise direction. T_1 will be attached to B and T_2 will be attached to A. i.e. tight side and slack side tensions will be changed.

Taking moments about "O"

$220 \times 200 + T_2 \times 50 = T_1 \times 100 \ldots..(2)$

By solving 1 & 2

$T_2 = 146.17$ N, $T_1 = 513$ N

$$\text{Torque} = (T_1 - T_2) \times r$$
$$= (513 - 146.17) \times 75 \times 10^{-3}$$
$$= 27.5 \text{N-m}$$

Linked Answer Questions (06 & 07)

06. **Ans: (b)**

Sol: d = 250 mm

$\rho = 7200$ kg/m^3

t = 20 mm

$\tau = 0.40$ sec

N = 500 rpm

Energy absorbed by brake

$$E = \frac{1}{2} I\left(\omega_2^2 - \omega_1^2\right)$$

$$I = mK^2 = \rho At\left(\frac{d}{2\sqrt{2}}\right)^2$$

$$I = 7200 \times \frac{\pi}{4}(0.25)^2(0.02)\left(\frac{0.250}{2\sqrt{2}}\right)^2$$

$$= 0.055 \text{ kgm}^2$$

$N_2 = 0 \rightarrow$ Stop

$$\Rightarrow E = \frac{1}{2}(0.05)\left(\frac{2\pi \times 500}{60}\right)^2 = 75 \text{ J}$$

07. **Ans: (d)**

Sol: Energy absorbed, $E = T \times \theta$

$$75 = T \times \left(\frac{\omega_1 + \omega_2}{2}\right) \times t$$

$$75 = T \times \left(\frac{\frac{2\pi \times 500}{60}}{2} + 0 \right) \times 0.4$$

$\Rightarrow$ T = 7.16 Nm

Linked Answer Question (08 & 09)

08. **Ans: (c)**

Sol: T = 800 N-m, r = 0.5 m

$T = (T_1 - T_2) \times r$

$$\Rightarrow T_1 - T_2 = \frac{800}{0.5}$$

$T_1 - T_2 = 1600$ N

But, $T_2 = 300$ N

$T_1 = 1900$ N

$$\frac{T_1}{T_2} = e^{\mu\theta} \Rightarrow \frac{1900}{300} = e^{0.45 \times \theta}$$

$$\theta = 235^0$$

09. **Ans: (c)**

Sol: $P_{max} = \frac{T_1}{r.W} = \frac{1900}{0.5 \times 0.03}$

$P_{max} = 126.67$ kPa

Common Data Question (10 & 11)

10. **Ans: (a)**

11. **Ans: (b)**

Sol: Given

d = 320 mm = 0.32 m

r = 160mm = 0.16m

$\mu = 0.3$

F = 600N

Taking moments about 'O'

$600(400 + 350) - F_t(200-160) = R_N(350)$

$600(750) - F_t(40) = R_N(350)$

$450000 - \mu R_N(40) = R_N(350)$ $(\because F_t = \mu R_N)$

$450000 - R_N(12) = R_N(350)$

$R_N(350) + R_N(12) = 45000$

$$R_N = \frac{450000}{362}$$

$R_N = 1243$N

For calculating breaking torque (T_B)

$F_t = \mu R_N$

$F_t = 0.3 \times 1243$

$F_t = 372.9$N

$T_B = F_t \times r = 372.9 \times 0.16 = 59.664$

$T_B = 60$Nm

Chapter- 11
Spur Gear Tooth

01. **Ans: (b)**

Sol: Given: $T_p = 25$

$N_p = 1200$ rpm , $N_G = 200$ rpm

$m = 4$, $C = ?$

$$C = \frac{m(T_p + T_G)}{2}$$

$$\frac{T_P}{T_G} = \frac{N_G}{N_P} \Rightarrow T_G = \frac{1200}{200}\times 25 = 150$$

$$C = \frac{4(25+150)}{2} = 350 \text{ mm}$$

02. **Ans (b)**

Sol: Given , $T_1 = 19$, $T_2 = 37$

$C = 140$mm

$$C = \frac{m(T_1 + T_2)}{2}$$

$$140 = \frac{m(19+37)}{2}$$

$$m = \frac{140\times 2}{56} = 5\text{mm}$$

03. **Ans: (c)**

Sol: $m = 80$ mm

Face width (w) = 90 mm

$F_t = 7.56$ kN

Tensile stress = 35 MPa = S

Form factor (y) = ?

Let $C_V = 1$

$F_t = SwmyC_v$

$7.56\times10^3 = 35\times10^6\times90\times8\times y$

$y = 0.3$

04. **Ans: (a)**

Sol: $P = 9$ kW , $N = 1440$ rpm

$d = 100$ mm , $F_t = ?$

$P = F_t \times V$

$$F_t = \frac{P}{V} = \frac{9\times10^3}{\frac{\pi\times0.1\times1440}{60}} = 1.19 \text{ kN}$$

05. **Ans (b)**

Sol: $P = 10$ kW $= 10\times10^3$W

$V = 600$m/min

$d = 100$mm $\Rightarrow r = 50$mm

$$F_t = \frac{P}{V}$$

$$= \frac{10\times10^3\times60}{600} = 10^3 \text{ N}$$

$F_t = 1$ kN

$$\text{Torque} = F_t \times r = \frac{1\times10^3\times50}{1000}$$

$T = 50$ N–m

06. **Ans: (b)**

Sol: Given $P = 20$ kW

$N_P = 300$ rpm

$\sigma_b = 80$ MPa

$y = 0.094$, $C_v = 1$

$w = 14$ m

$T_p = 18$, $m = ?$

$$F_t = \frac{P}{V} = SwmyC_v \times \pi$$

$$\Rightarrow \frac{20\times10^3}{\left(\frac{\pi d_p \times 300}{60\times1000}\right)} = 80\times10^6\times(14m)m\times 0.094\times1\times\pi$$

$(\because d_p = mT_p)$

$$\Rightarrow \frac{20\times10^6\times60}{\pi\times18\times m\times300} = 80\times14\times0.094\times\pi\times m^2\times10^6$$

$$\Rightarrow m = 5.98 \approx 6$$

Linked Answer Questions (07 & 08)

07. **Ans: (a)**

08. **Ans: (b)**

Sol: $P = 11$ kW , $N_P = 1440$ rpm

$\phi = 14\frac{1}{2}$, $m = 6$ mm

$T_P = 25$, $y = 0.1$, $C_v = 0.21$

$$\frac{T_G}{T_p} = \frac{N_P}{N_G} = 3:1$$

$T_{max} = 1.5\, T_{mean}$

$S = 210$ MPa

$F_t = ?$, $w = ?$

$$F_t = \frac{P}{V}C_s \qquad \left(\because V = \frac{\pi dN}{60}\right)\ (d = mT)$$

$$F_t = \frac{11\times10^3}{\frac{\pi(6\times25)\times1440}{60\times1000}}$$

$F_t = 0.98$ kN

$F_t = S\,w\,m\,y\,C_v$

$0.98\times 10^3 = 210\times\ w\ \times 6\times 0.1\times 0.21\ w$

$= 37$ mm

Linked Answer Questions (09 to 11)

09. **Ans: (b)**

Sol: $P = 500$ kW

$N_P = 1800$ rpm

$C = 660$ mm

$\phi = 22\frac{1}{2}$

$m = 8$ mm

$\frac{T_G}{T_P} = 10:1$

$F_n = 200\ \frac{N}{mm}$

$$C = \frac{m(T_G + T_P)}{2}$$

$$660 = \frac{8(T_P + 10T_P)}{2}$$

$T_P = 15$

$T_G = 150$

$d_p = mT_p = 8(15) = 120$ mm

$F_t = ?$

F_r on bearing = ?

$w = ?$

$$F_t = \frac{P}{V} = \frac{500(kW)}{\frac{\pi d_p N_p}{60}}$$

$$= \frac{500\times10^3}{\pi\left(\frac{120}{1000}m\right)\times\left(\frac{1800}{60}\right)\frac{1}{sec}}$$

$F_t = 44.2$ kN

10. **Ans: (c)**

Sol: $F_r = F_t \, . \, \text{Tan}\, \phi$

$= 44.2 \text{ Tan } (22.5) = 18.3 \text{ kN}$

$$F_n = \frac{F_t}{\cos\phi} = \frac{44.2}{\cos 22.5} = 47.85$$

11. **Ans: (d)**

Sol: 200 N $\rightarrow$ 1 mm width

47.85 kN $\rightarrow$?

$$w = \frac{47.85\times10^3}{200} = 240 \text{ mm}$$

12. **Ans: (c)**

Sol: S_{teel} = 120 MPa $\rightarrow$ for pinion

S_{CI} = 100 MPa $\rightarrow$ for gear

Form factors

For gear, for pinion $(y_{CI})_g = 0.13$

Form factors

$(y_{steel})_p = 0.093$

$S_{steel} \times y_{steel} = 120 \times 0.093 = 11.16$

$S_{CI} \times y_{CI} = 100 \times 0.13 = 13$

$\therefore \; S_{steel} \times y_{steel} < S_{CI} \times y_{CI}$

$\therefore (\text{Strength})_{pinion} < (\text{Strength})_{gear}$

So Pinion is weaker than gear

13. **Ans: (b)**

Sol: Given:

$$G.R = \frac{T_G}{T_P} = 2$$

w = 10 cm = 100 mm

d_p = 40 cm = 400 mm

Stress factor for fatigue = 1.5 N/mm^2

= K

$$Q = \frac{2T_G}{T_G + T_P} = \frac{2(2T_P)}{2T_P + T_P} = \frac{4}{3}$$

$F_w = K d_p w Q$

$$F_w = (1.5)(400)(100)\frac{4}{3} = 80 \times 10^3$$

= 80 kN