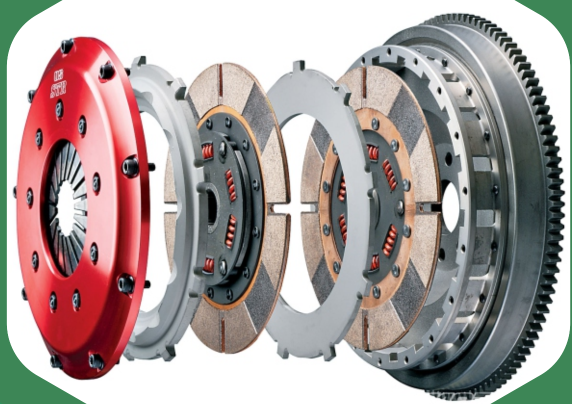
GATE | PSUs

MECHANICAL ENGINEERING

Machine Design

Text Book : Theory with worked out Examples and Practice Questions



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Machine Design

Solutions for Text Book Practice Questions

Chapter 1 Static Loads

01. Ans: (d)

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

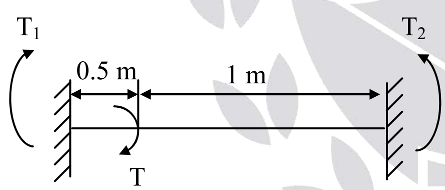
E = 100 GPa

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

$$\sigma_b = \frac{100\times10^3\times\left(\frac{0.2}{2}\right)}{\left(\frac{25}{2}\right)} = 800\,\text{MPa}$$

02. Ans: (b)

Sol:



$T = T_1 + T_2$

$\theta = \theta_1 = \theta_2$

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

$$T_1 = \frac{7358\times1}{1.5} = 4905.33\ \text{Nm}$$

$$T_2 = \frac{7358\times0.5}{1.5} = 2452.66\,\text{Nm}$$

Maximum shear stress

$$\tau = \frac{16T_1}{\pi d^3} = \frac{16\times4905.33\times10^3}{\pi\times80^3} = 48.8\ \text{MPa}$$

03. Ans: (a)

Sol: $G = 0.8\times10^3$ MPa

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

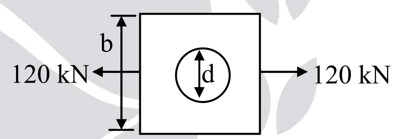
$$\theta_1 = \frac{4905.33\times10^3\times0.5\times10^3}{\frac{\pi}{32}\times80^4\times0.8\times10^5}$$

$= 7.62\times10^{-3}$ radian

$= 7.62\times10^{-3}\times\dfrac{180}{\pi} = 0.436$ degrees

04. Ans: (b)

Sol:



P = 120 kN, t = 13 mm

$$\frac{120\times10^3}{(b-d)t} = 75\,\text{MPa}$$

$$\frac{120\times10^3}{(b-22)\times13} = 75$$

$\Rightarrow$ b = 145 mm

05. Ans: (b)

Sol: Force applied on the bar $= 95\times100\times t$ N

Maximum stress induced

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

$$= \frac{95\times100\times t}{(100-5)\times t} = 100\,\text{MPa}$$

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: (b)

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

$F_S = 18$ kN $\qquad FS = ?$

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

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

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

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

$$= 50\ \text{MPa}$$

According to maximum shear stress theory

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

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

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

04. Ans: (d)

Sol: Given thin cylindrical shell

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

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

$\sigma_3 = 0$

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

i.e.,
$$\left|\frac{30.18-15.08}{2}\right| = 7.55$$
$$\left|\frac{30.18-0}{2}\right| = 15.09$$
$$\left|\frac{15.08}{2}\right| = 7..54$$

$\tau_{max} = 15.09$

According max shear stress theory

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

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

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

05. Ans: (c)

Sol: $\sigma_t = 200$ MPa $= \sigma_1$

$\sigma_c = -100$ MPa $= \sigma_2$

$S_{yt} = 500$ 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

06. Ans: (b)

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

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

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

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

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

07. Ans: (a)

Sol: $F_T = 20$ kN, $F_s = 15$ kN

$S_{yt} = 360$ 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

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

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

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

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

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

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

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

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

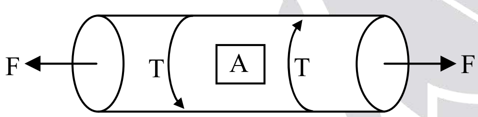
$$= \frac{10^3}{A}\sqrt{20^2+3\times15^2} = \frac{360}{3}$$

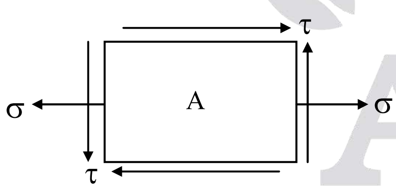
$\therefore$ A = 273.22 mm^2 = (π/4) d^2

$\Rightarrow$ d = 18.65mm

08. Ans: (b)

Sol:





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

F = 40 kN ,

d = 20 mm, T = ?

According to Distortion Energy Theory

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

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

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

$\Rightarrow \tau$ = 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

09. 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

$$\tau = \frac{16T}{\pi d^3} = \frac{16\times2.5\times10^3}{\pi\times(0.1)^3}$$

= 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

10. 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 ×1500 + 5 × 500

= 10000 ×10^{3}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

11. Ans: (b)

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

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

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

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

According Distortion Energy Theory

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

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

12. 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

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

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

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

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

$\Rightarrow$ FS = 2.7

Chapter 3 Fluctuating Loads

01. 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

$S_e = K_a\, K_b\, K_c\, K_d\, S_e'$

$S_e' = 0.5\, S_{ut}$

$= 0.5\times440 = 220$MPa

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

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

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

$\therefore\ S_e = 48.63$MPa

For completely reverse load

$\sigma_m = 0$

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

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

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

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

$\therefore\ t = 12.3$ mm

$t = 12$ mm

02. Ans: (b)

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

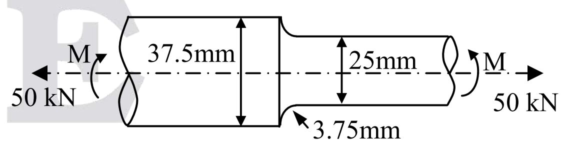
$S_e' = 200$ MN/m^2, $K_t = 1.55$, $q = 0.9$

$M = ?$

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

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

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



$$\text{Mean stress, } \sigma_m=\frac{F}{A}$$

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

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

According to Goodman's equation

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

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

$\Rightarrow$ M = 135.5 N-m

03. Ans: (b)

Sol: Given:

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

$\sigma_2 = 25$ MPa to 175 MPa

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

$K_t = 1.85$

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

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

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

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

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

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

$\Rightarrow$ F.S = 1.2

Common Data for Questions 04 & 05

04. Ans: (c) & 05. Ans: (a)

Sol: $S_e = 280$ MPa

$S_f = 0.9\, S_{ut}$ for 10^3 Cycles

$S_u = 600$ MPa

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

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 (1) and (2),

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

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

$\Rightarrow \quad L = 1.4 \times 10^4$ cycles

06. 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

$L_2 = 0.4 \times 10^5$ cycles

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

$L_3 = 0.15 \times 10^5$ cycles

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

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

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

$L = 42352.94$ Cycles

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

42352.94 cycles $\rightarrow$? L

$\Rightarrow L = 19.6$ hrs

07. 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

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

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

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

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

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

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

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

$\Rightarrow$ FS = 2.04

08. Ans: (c)

Sol: $L_1 = 10$ hours

$N_1 = 9.8$ hours

$N_2 = 8.2$ hours

$L_2 = ?$

According to Miner's Equation,

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

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

$L_2 = 410$ hours

Common Data for Questions 09 & 10

09. Ans: (c) & 10. Ans: (d)

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

$\sigma_{min} = -130$ MPa

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

$$S_e = K_a K_b K_c K_d S_e^{'}$$

$$= 0.76\times0.85\times0.897\times\frac{1}{1+0.95(1.85-1)}(0.5\times1400)$$

$= 224.411$ MPa

$\therefore$ For a completely reversed,

$\sigma_m = 0$;

$\sigma_a = 130$ MPa

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

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

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

$$\sigma_{meq} = \sqrt{\sigma_m^2+3\tau_m^2} = \sqrt{3\times36.5^2}$$

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

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

$= 134.76$ MPa

According to Goodman's equation,

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

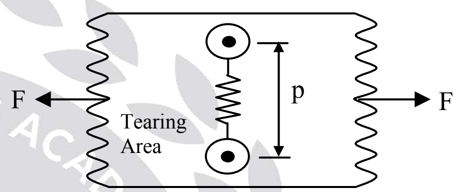
$$\frac{134.76}{224.4}+\frac{63.21}{1400} = \frac{1}{FS}$$

$\Rightarrow FS = 1.54$

Chapter 4 Riveted Joints

01. Ans: (b)

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



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

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

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

$= 0.5\times100 = 50$ %

Common Data Question (02, 03, 04)

Given, d = 30 mm

$\sigma_t = 40$ MPa $= 40$ N/mm^2

P = 90 mm

$\sigma_s = 30$ MPa $= 30$ N/mm^2

t = 12.5 mm

$\sigma_c = 55$ MPa $= 55$ N/mm^2

02. Ans: (b)

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

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

$= \dfrac{2}{3}\times 100$

$\eta_{Tearing} = 66.67\%$

03. Ans: (b)

Sol: Strength of Riveted plate = P = p×t×σ_t

P = 90 ×12.5 × 40

= 45000 N

Shearing Resistance,

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

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

= 21206N

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

= 0.47 = 47%

04. Ans: (c)

Sol: Crushing Strength

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

= 30 × 12.5 × 55

= 20625 N

Tearing Strength

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

= (90 – 30)×12.5 × 40 = 30,000 N

Shear Strength

P_S = 21206 N ,

P = 45000 N

Strength of riveted joint

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

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

05. Ans: (c)

Sol: Given t = 7 mm

τ_s = 60 MPa = 60 N/mm^2

σ_c = 120 MPa = 120 N/mm^2

n = 3 (Triple riveted joint)

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

$= 3\times\dfrac{\pi}{4}d^2\times 60 = 141.4d^2\,N$ ……(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

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

06. Ans: (d)

Sol: Given:

t = 7 mm,

n = 3

σ_t = 80 MPa = 80 N/mm^2

τ_s = 60 MPa = 60 N/mm^2

σ_c = 120 MPa = 120 N/mm^2

Let p = pitch of rivets,

$d = 18$ mm

Tearing resistance is

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

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

$= 560(p - 18)$ N ……. (1)

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

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

From equations (1) and (2)

$560(p-18) = 45804$

$p = 99.79$

$p \cong 100$ mm

07. Ans (a)

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

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

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

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

08. Ans: (b)

Sol: Given:

$\tau_s = 100 \text{ MPa} = 100 \text{ N/mm}^2$

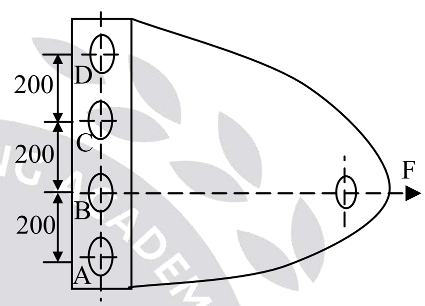
$d = 20$ mm, $n = 4$

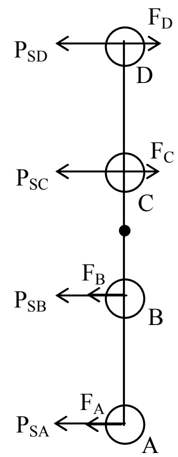
Direct shear load on each rivet

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

$P_A = P_B = P_C = P_D = P_S$

All dimensions are in mm





From figure,

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

$l_B = l_C = 100$ mm

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

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

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

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

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

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

$F_A = F_B = 0.15$ 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

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

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

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

09. Ans: (b)

Sol: Tensile load (F_t)

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

$= (60-20) \times 15 \times 120 = 72000\text{N}$

$= 72\text{ kN}$

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

$= 28274.33\text{ N} = 28.274\text{ kN}$

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

$= 20 \times 15 \times 160$

$= 48000\text{ N} = 48\text{ Kn}$

Load carrying capacity (F)

$=$ Minimum of (F_t, F_s & F_c)

$= 28.274\text{ kN}$

Linked Answer Questions 10 & 11:

10. Ans: (a)

Sol: No. of Rivets = 2

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

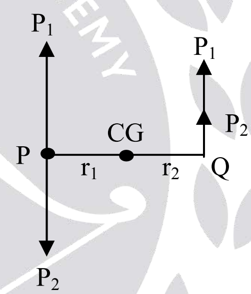
Secondary shear load $P_2 = \frac{Per_1}{r_1^2 + r_2^2}$

$$= \frac{4 \times 10^3 \times (1.8 + 0.2) \times 0.2}{0.2^2 + 0.2^2}$$

$= 20000\text{ N} = 20\text{ kN}$

11. Ans: (b)

Sol:



Resultant load on Rivet P $= P_2 - P_1$

$= 18\text{ kN}$

Resultant shear stress on Rivet P

$$= \frac{18 \times 10^3}{\frac{\pi}{4} \times 12^2} = 159\text{ MPa}$$

Chapter 5 Threaded Fasteners

01. Ans: (b)

Sol: Given d = 24 mm

$F_i = 2840\ d = 2840 \times 24$

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

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

$$\sigma_t = \frac{2840 \times 24}{\frac{\pi}{4}(0.84 \times 24)^2}$$

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

02. Ans: (c)

Sol: Given

d = 36 mm

$d_c = 0.84\ d = 0.84 \times 36$

F.S = 1.5

$S_{yt} = 280$ MPa

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

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

$$= \frac{\pi}{4}(0.84 \times 36)^2 \times \frac{280}{1.5}$$

= 134066 N

P = 134 kN

03. Ans: (d)

Sol: Given pitch = 4 mm

Torque (T) = 1.4 kN-mm

Work done = force ×distance

Force×distance = Torque× Angle of rotation

$F \times 4 = T \times \theta$

$$F = \frac{1.4 \times 2\pi}{4} = 2.199 \text{ kN} = 2.2 \text{ kN}$$

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: (b)

Sol: Given

D = 250 mm

Pressure = 12 bar = 1.2 MPa

F.S = 5

$S_{yt} = 300$ MPa

n = 8

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

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

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

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

$\Rightarrow A_b = 122.66\ mm^2$

06. Ans: (d)

Sol: Given,

$D = 500$ mm

$n = 8$

$P = 20$ 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 $\times$A

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

For leak proof joint $F_m \le 0$

$F_i = (1-C)\,P$

$F_i = (1-0.25)\,49$

$= 36.75\ kN \approx 37\ kN$

Linked Answer Q 07 & 08

07. Ans: (d)

Sol: $S_{yt} = 650$ MPa

$A = 115\ mm^2$

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

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

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

$F_i = 0.8S_{yt}\times A$

$= 0.8\times650\times115 = 59800$ N

For bolt,

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

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

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

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

08. 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

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

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

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

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

$$CP = \frac{650}{1}\times115 - 59800$$

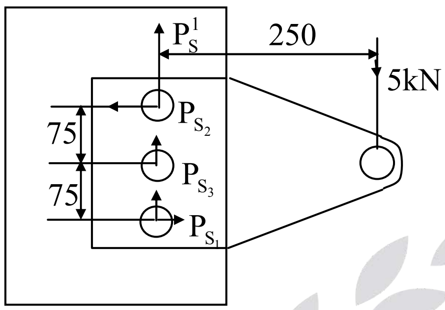
$CP = 14950$

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

09. 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}

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

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

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

$$= 8.498 \text{ kN}$$

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

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

$$\therefore d = 12.74\text{mm} \approx 13\text{mm}$$

10. Ans: (a)

Sol: n = 4

P = 10 kN

S_{yt} = 400 N/mm^2

FS = 6

d_c = 0.8d

Using Rankine theory

$P_A = CL_2$ (tensile load)

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

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

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

Bolt 'A' is subjected to maximum load

Rankine Theory

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

= 8+ 2.5 = 10.5kN

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

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

d_c = 14.16

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

11. Ans: (c)

Sol: Given

n = 4 , P = 5 kN

S_{yt} = 380 N/mm^2

F.S = 5 , d_c = 0.8 d

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

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

$$= \frac{5\times 250}{2(75^2+375^2)}\times 375 = 1.6 \text{ kN}$$

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

Direct shear load,

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

Bolts at 'A' is under maximum bending

Rankine Theory

$$\tau = \frac{P_{SA}}{A} = \frac{1.25\times10^3}{A}$$

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

$$\sigma_t = \frac{P_{tA}}{A} = \frac{1.6\times10^3}{A}$$

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

$$\sigma_1 = \frac{1.6\times10^3}{2A} + \frac{1}{A}\sqrt{\left(\frac{1.6\times10^3}{2}\right)^2 + \left(1.25\times10^3\right)^2}$$

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

According to Rankine Theory

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

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

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

$$\Rightarrow d_c = 6.196 \text{ mm}$$

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

Chapter 6 Welded Joints

01. Ans (b)

Sol: Given: s = 10 mm ,

τ = 80 MPa

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

$= 0.707\times10 \times 10 \times 80 = 5.6\text{kN}$

02. Ans (b)

Sol: Given, P = 400 kN ,

τ = 80 MPa

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

$$400\times1000 = 2\times.707\times10\times80\times l$$

$$2l = \frac{400000}{0.707\times10\times80}$$

Total length = $2l \approx 703$ mm

03. Ans: (a)

Sol: Given:

P = 340 kN = 340000 N

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

s =15 mm

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

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

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

04. Ans: (b)

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

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

$$4 \text{ kN} \rightarrow 1 \text{ cm}$$

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

$$\therefore\ l + 100 + l = 450$$

$$\therefore\ l = 175 \text{ mm}$$

05. Ans (a)

Sol: Given: $d = 60$ mm, $s = 10$ mm,
$\tau = 70$MPa

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

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

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

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

s = Size of the weld

$$T = \frac{70 \times \pi \times 10 \times (60)^2}{2.83}$$

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

06. Ans (a)

Sol: $t = 10$ mm

$d = 15 \times 10^3$ mm

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

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

According to Rankine Theory

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

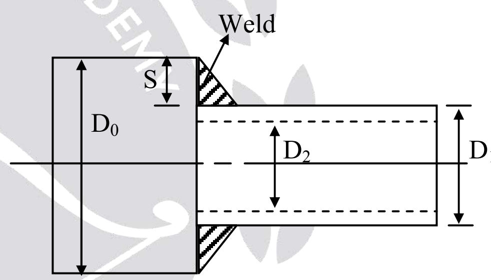
$$\frac{pd}{4t} = 85$$

$$\Rightarrow \frac{p \times 15 \times 10^3}{4 \times 10} = 85$$

$$\Rightarrow p = 0.226 \text{ MPa}$$

07. Ans: (b)

Sol:



$D_1 = 205$ mm,

$D_2 = 200$ mm

$D_0 = 210$ mm,

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

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

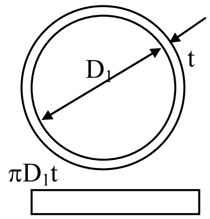
$t = 0.707\ s = 0.707 \times 2.5 = 1.7675$ mm

Force = Pressure × Area

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

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

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

Linked questions (Q.08 &Q.09)

08. Ans: (a)

09. 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

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

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

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

$l = 377.18$ mm

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

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

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

P = 54.9 kN ≈ 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

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

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

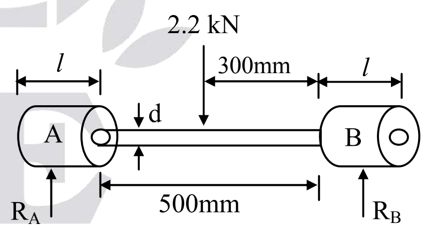
$$= \frac{3000}{1.3 \times 40}$$

$l = 57.69$ 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 $\quad$ l = 500 mm

W = 2.2 kN $\quad$ 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/mm^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) $= 9$ kN $= 9000$ N

$C = 0.075$ mm,

Diametral clearance

$(C_d) = 2\times0.075 = 0.15$ mm

$= 0.15\times10^{-3}$ 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

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

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

$$\mu = 0.0157 \text{ Pa} - \text{sec}$$

06. Ans: (a)

Sol: Given:

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

$p = 2$ MPa , $N = 500$ rpm

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

Heat lost in friction = f× W×V

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

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

$$= 14.72 \text{ Nm/sec}$$

$14.72 = CA\,(T_s - T_r)$

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

$T_s = 70.2°C$

Linked Answer Question 07 & 08

07. Ans: (a)

08. Ans: (c)

Sol: Given:

$d = 100$ mm = 0.1 m

$l = 150$ mm = 0.15 mm

$W = 4.5$ kN = 4500 N

$N = 600$ rpm

$\mu = 18.5\times10^{-3}$ 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

$p = 1.6$ N/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

$\mu = 0.05$

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

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

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

Chapter 8 Rolling Contact Bearings

01. 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

02. 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 (03 & 04)

03. Ans: (a)

04. 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

$P = [(0.56 \times 1 \times 2.5) + (1.4 \times 1.5)]1.5$

$P = [11.4 + 2.1]1.5$

$P = (3.5)(1.5)$

$P = 5.25$ 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 (05 & 06)

05. Ans: (c)

06. 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

$$= \left[\frac{(270\times5^3)+(576\times7^3)+(216\times3^3)}{270+576+216}\right]^{1/3}$$

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

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

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 (07 to 10)

07. Ans: (b)

08. Ans: (a)

09. Ans: (b)

10. Ans: (a)

Sol: Given:

$T_1 = 3$ kN

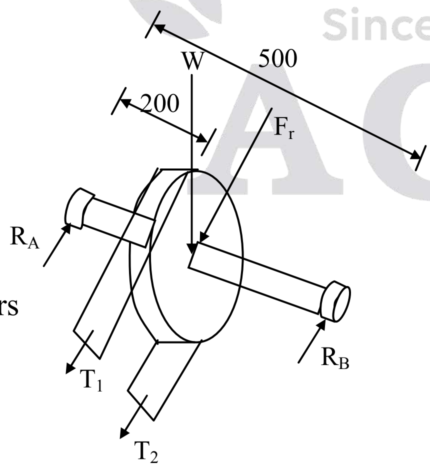
$T_2 = 1.5$ kN

$F_a = 2$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 = 22.44 kN

Chapter 9 Clutch Design

01. Ans: (b)

Sol: Given,

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

$r_1 = 150$ mm $= 0.15$ mm

$r_2 = 100$ mm $= 0.1$ mm

$\mu = 0.5$

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

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

$$R = 125 \text{ mm}$$

Torque Transmitted,

$$T = n\mu WR$$

(For both sides effective n = 2)

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

$$= 125000 \text{ N–mm}$$

$$T = 125 \text{ N–m}$$

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

$d_1 = 1.25d_2$

$r_1 = 1.25r_2$

$\mu = 0.3$

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

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

$[\because W = 2\pi C(r_1 - r_2),\ C = p_1 r_1 = p_2 r_2]$

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

$$100\times 10^3 = (0.3)2\pi(0.085)(r_2)[(1.25r_2)^2 - r_2^2]$$

$r_1 = 130$ mm, $d_1 = 260$ mm

$r_2 = 104$ mm, $d_2 = 208$ mm

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

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

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

$$W = 1.44 \text{ kN}$$

04. Ans: (c)

Sol: Given,

$\mu = 0.5$

$r_1 = 150$ mm $= 0.15$ m

$r_2 = 100$ mm $= 0.1$ m

$T = 0.4$ kN–m $= 400$ N–m

$n_1 + n_2 = 5$,

n = No. of pairs of contact surface

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

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

$$T = n\mu W R$$

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

$$W = 1600 \text{ N}$$

$\because$ Four springs exert axial load,

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

Linked Answer Question (05 & 06)

05. 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

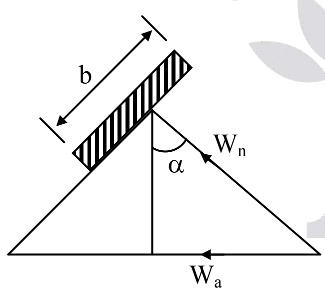
$$T = \frac{60P}{2\pi N} = \mu W_n r_m = \mu W_n\left(\frac{r_1 + r_2}{2}\right)$$

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

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

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

$W_a = 1323.60$ 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

06. 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. 07& 08

07. Ans: (c)

08. 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,

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

$$83.6\times 10^3 = \frac{2}{3}\times 0.3\times W\left[\frac{100^3 - 60^3}{100^2 - 60^2}\right]\times 2$$

W = 1706.12 N

09. Ans: (d)

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

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

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

$\omega_1 = 0.75\omega_2$,

$n = 4$

$$318.3 = 4\times0.25\times m\times 0.125\left(1-\frac{9}{16}\right)\times 78.5^2\times0.15$$

m = 6.3 kg

10. Ans: 157 mm & 135.22 mm

Sol: Centrifugal force between each shoe and drum

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

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

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

Length = 157 mm

Width = 135.22 mm

Chapter 10

Brakes

Linked Answer Questions (01 & 02)

01. Ans: (b)

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

$300\times500 = R_N\times200$

$R_N = 750$ N

$F_t = \mu R_N = 180$ N

$T = F_t\, r$

$$= 180\times\left(\frac{300}{2}\right)\times10^{-3} = 27\ \text{N-m}$$

02. Ans: (a)

Sol: $$\omega_1 = \frac{2\pi\times100}{60} = 10.47\ \text{rad/sec}$$

$\omega_2 = 0$

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

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

$= 27\times5.235\times5 = 706.725$ J

03. Ans: (b)

Sol: $\mu = 0.3$

$2\theta = 90° = \pi/2$ rad

$\theta = 45°$

Equivalent coefficient of friction

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

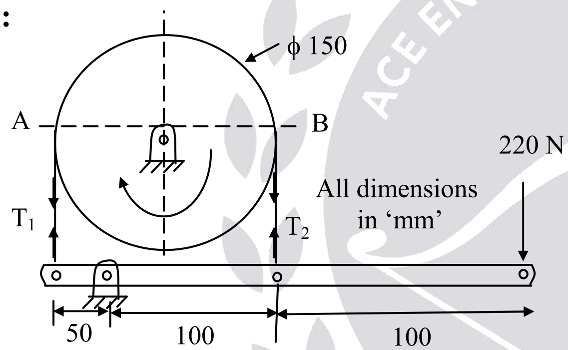
$$= \frac{4 \times 0.3 \times \sin 45^0}{\pi/2 + \sin 90^0}$$

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

Common Data Question 04 & 05

04. Ans: (c)

Sol:



T = 450 N-m μ = ?

P = 220 N a = 50 mm

b = 100 mm

$\sum M_{pivot} = 0$

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

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

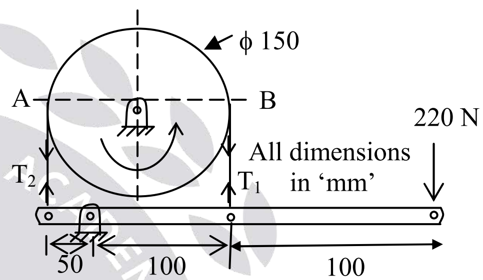
$$\frac{T_1}{T_2} = e^{\mu \times \theta}$$

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

$$\Rightarrow \mu = 0.199 = 0.2$$

05. Ans: (a)

Sol:



We know that

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

Here, μ = 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)

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

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

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

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"

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

By solving 1 & 2

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

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

$= (513 - 146.17) \times 75 \times 10^{-3}$

$= 27.5$ 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

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

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

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

$= 0.055$ 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

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

$\theta = 235°$

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

$r = 160$ mm $= 0.16$ m

$\mu = 0.3$

$F = 600$ N

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: $T_p = 25$, $m = 4$, $C = ?$

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

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

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

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

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: $m = 8$ mm

Face width (w) $= 90$ mm

$F_t = 7.56$ kN

Tensile stress $= 35$ MPa $= S$

Form factor (y) $= ?$

Let $C_V = 1$

$F_t = SwmyC_v$

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

$\Rightarrow$ $y = 0.3$

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: $P = 10 \text{ kW} = 10\times10^3 W$

V = 600 m/min

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

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

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

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

σ_b = 80 MPa

y = 0.094,

C_v = 1

w = 14 m

T_p = 18,

m = ?

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

$$\Rightarrow \frac{20\times10^3}{\left(\frac{\pi d_p\times300}{60\times1000}\right)} = 80\times10^6\times(14m)m\times 0.094\times1\times\pi$$

($\because d_p = mT_p$)

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

$\Rightarrow m = 5.98 \approx 6$

Linked Answer Questions 07 & 08

07. Ans: (b)

08. Ans: (a)

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 = ?

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

$$F_t = \frac{11\times10^3}{\frac{\pi(6\times25)\times1440}{60\times1000}}\times1.5$$

F_t = 1.46 kN

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

$1.46\times 10^3 = 210\times w \times 6\times 0.1\pi\times 0.21$

$\Rightarrow$ w = 18 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: $F_r = F_t . \text{Tan}\ \phi$

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

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

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 $= K$

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

$F_w = Kd_pwQ$

$$F_w = (1.5)(400)(100)\frac{4}{3} = 80\times10^3$$

$= 80$ kN

Chapter 12
Springs

01. Ans: (d)

Sol: Let, n = no. of active coils of spring

$$k = \frac{Gd^4}{8D^3n}$$

For a given spring G, d, D are constant

$$k \propto \frac{1}{n}$$

$$\frac{k_2}{k_1} = \frac{n_1}{n_2}$$

$$k_2 = \frac{n}{n/3} \times k_1$$

$\Rightarrow \quad k_2 = 3\ k$

02. Ans: 668.4 MPa

Sol: Given, C = 10

k_s = direct shear stress factor

$$= 1 + \frac{1}{2C}$$

$$= 1 + \frac{1}{20} = \frac{21}{20}$$

$$\tau_{max} = k_s \frac{8F \times D}{\pi d^3} = \frac{21}{20} \times \frac{8 \times 3600}{4 \times (36\pi)} \times 10$$

τ_{max} = 668.45 MPa

03. Ans: (b)

Sol: Wire of spring experiences direct shear load and twisting moment due to axial load which passes through the axis of spring.

04. Ans: 10

Sol: Given,

$$\frac{\tau_{max}}{\delta} = \frac{10}{\pi}$$

$$\frac{8FD/\pi d^3}{8FD^3n/G\,d^4} = \frac{10}{\pi}$$

$$\frac{G \times d}{\pi D^2 n} = \frac{10}{\pi}$$

$$\frac{80 \times 10^3 \times 8}{800\pi \times D} = \frac{10}{\pi}$$

D = 80 mm

$\Rightarrow \ell = \pi D n = 800\pi$

$\Rightarrow$ n = 10

05. Ans: (b)

Sol: $\delta = \dfrac{F}{k_{eq}} = \dfrac{F}{3k + 5k} = \dfrac{F}{8k}$

06. Ans: 300

Sol: $\delta = \dfrac{3}{8} \dfrac{WL^3}{n\,b\,t^3\,E}$

$$15 = \frac{3}{8} \times \frac{3600 \times 1800^3}{6 \times b \times 12^3 \times 200 \times 10^3}$$

$\Rightarrow$ b = 253.125 mm

$$\sigma = \frac{3\,W\,L}{2\,n\,b\,t^2}$$

$$37.5 = \frac{3 \times 3600 \times 1800}{2 \times 6 \times b \times 12^2}$$

$\Rightarrow$ b = 300

Safe width = 300 mm