Solution of Mid-Term Exam

2nd Metallurgy
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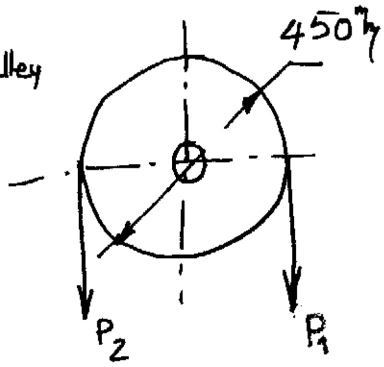
Problem # 1

① The torque transmitted by the shaft is given by:

$$\text{Power} = T \cdot \omega$$

$$\therefore T = \frac{P}{\omega} = \frac{20 \times 10^3}{\frac{2\pi}{60}(500)} = 381.97 \text{ N.m}$$

For belt pulley: $P_1 = 3P_2$

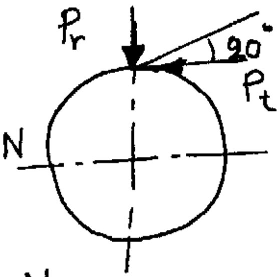


$$T = (P_1 - P_2) \cdot \frac{D_{pulley}}{2} = (3P_2 - P_2) \cdot \frac{D_{pulley}}{2} = \frac{2P_2}{2} \cdot D_{pulley}$$

$$\therefore P_2 = \frac{T}{D_{pulley}} = \frac{381.97}{450 \times 10^{-3}} = 848.82 \text{ N}$$

$$\therefore P_1 = 3P_2 = 3 \times 848.82 = 2546.46 \text{ N}$$

For Gear:



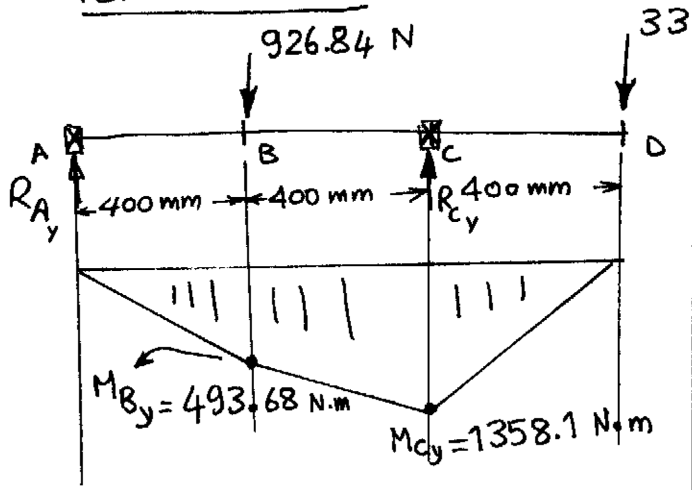
ϕ = pressure angle = 20°

$$\text{Power} = P_t \cdot V = P_t \cdot \omega \cdot \frac{D_{Gear}}{2}$$

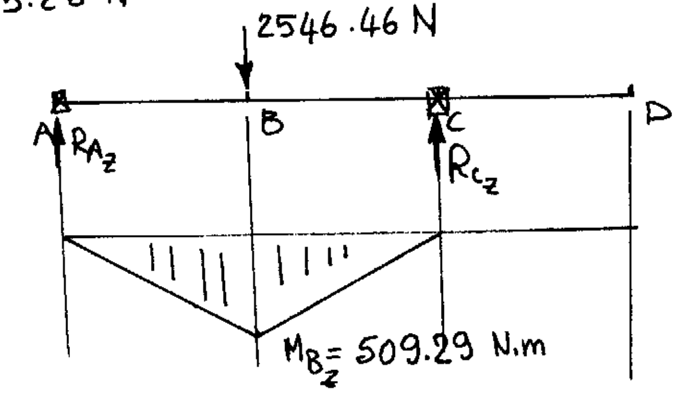
$$\therefore P_t = \frac{2 \times \text{Power}}{\omega \times D_{Gear}} = \frac{2 \times 20 \times 10^3}{\frac{2\pi}{60}(500) \times 300 \times 10^{-3}} = 2546.46 \text{ N}$$

$$P_r = P_t \tan\phi = 2546.46 \times \tan 20 = 926.84 \text{ N}$$

Vertical Plane X-Y plane



Horizontal Plane X-Z Plane



Force Analysis X-Y Plane:

$$R_{A_y} + R_{C_y} = 4322.12$$

$$\Sigma M_A = 0$$

$$926.84(400) + 3395.28(1200) = R_{C_y}(800)$$

$$\therefore R_{C_y} = 5556.34 \text{ N}$$

$$\therefore R_{A_y} = 1234.22 \text{ N}$$

Force Analysis X-Z Plane:

$$R_{A_z} + R_{C_z} = 2546.46$$

$$\Sigma M_A = 0$$

$$2546.46(400) = R_{C_z}(800)$$

$$\therefore R_{A_z} = R_{C_z} = \frac{2546.46}{2} = 1273.23 \text{ N}$$

$M_B = \sqrt{M_{B_y}^2 + M_{B_z}^2} = \sqrt{(493.68)^2 + (509.29)^2} = 709.3 \text{ N.m}$

$M_c = 1358.1 \text{ N.m}$

$\therefore$ Critical section is "C" ..

$\therefore \; M_b = 1358.1 \text{ N.m}$

$M_t = 381.97 \text{ N.m}$

$K_b = 1 \;, \; K_t = 1.5$

or $S_y = 460 \text{ MPa} \; ; \; \tau_y = \frac{S_y}{2} = 230 \text{ MPa}$

take $F.S = 2$

$\therefore \tau_{all} = \frac{\tau_y}{F.S} = \frac{230}{2} = 115 \text{ MPa}$

$$d^3 = \frac{16}{\pi \tau_{all}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} = \frac{16}{\pi \times 115 \times 10^6} \sqrt{(1358.1)^2 + (1.5 \times 381.97)^2}$$

$\therefore d = 0.04026 \text{ m} = 40.26 \text{ mm}$

$\therefore$ take $d = 42 \text{ mm}$.

② $L = 20'000$ hrs

Required $C = ?$ at bearing (A)

$R_A = P = \sqrt{R_{A_y}^2 + R_{A_z}^2} = \sqrt{(1234.22)^2 + (1273.23)^2} = 1773.25 \text{ N}$

or $L = \left(\frac{C}{P}\right)^3$ or $L_h = 20\,000$ hrs

$$L = \frac{60 \, n \, L_h}{10^6} = \frac{60 \times 500 \times 20000}{10^6} = 600 \text{ million rev.}$$

$\therefore L^{1/3} = \frac{C}{P} \qquad \therefore C = P L^{1/3}$

$C = 1773.25 \times (600)^{1/3} = 14\,956 \text{ N}$

Problem # 2

Power = 45 kW ; 1440 RPM

N = 8 bolts

P.C.D = 150 mm (Rigid Coupling)

S_y = 380 MPa

F.S = 2.5

a) Diameter of bolts?

$$\tau = \frac{8 M_t}{\pi D N d^2}$$

$$\tau_y = \frac{S_y}{2} = \frac{380}{2} = 190 \text{ MPa}$$

$$\tau_{all} = \frac{\tau_y}{F.S} = \frac{190}{2.5} = 76 \text{ MPa}$$

$$\therefore 76 \times 10^6 = \frac{8 M_t}{\pi D N d^2}$$

$\therefore$ Power $= M_t \times \omega$ $\therefore$ $M_t = \dfrac{45 \times 10^3}{\frac{2\pi}{60}(1440)} = 298.4$ N.m

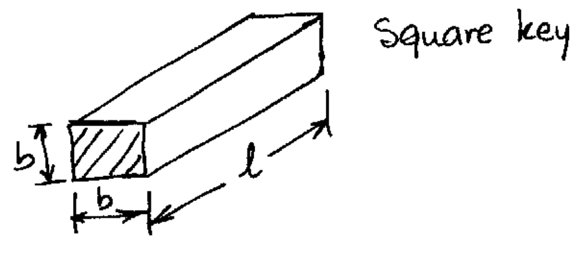
$$\therefore 76 \times 10^6 = \frac{8 \times 298.4}{\pi (0.150) \times 8 \times d^2} \quad \therefore d = 2.886 \times 10^{-3} \text{ m}$$

$\therefore d = 2.88$ mm

$d_o = \dfrac{d}{0.85} = 3.4$ mm $\therefore$ take M4 bolts.

b) D = 40 mm

Key (b×b×l)



$b = \dfrac{D}{4} = 10$ mm.

$S_y = 620$ MPa

$\tau_y = 310$ MPa

take a F.S = 2 $\therefore \tau_{all} = 155$ MPa. $S_{all} = 310$ MPa.

Shear: $\tau = \dfrac{2 M_t}{D b l}$ $\qquad l = \dfrac{2 M_t}{\tau_{all}\, b D} = \dfrac{2 \times 298.4}{155 \times 10^6 \times 10 \times 10^{-3} \times 40 \times 10^{-3}} = 9.6$ mm

Compression: $\sigma = \dfrac{4 M_t}{D b l}$ $\qquad l = \dfrac{4 M_t}{\sigma_{all}\, D b} = \dfrac{4 \times 298.4}{310 \times 10^6 \times 10 \times 10^{-3} \times 40 \times 10^{-3}} = 9.6$ mm

$\therefore$ take $l = 10$ mm (minimum length Required)