Question (1)

A: pulley A : $d_A = 250$ mm, $P_2 = 0.2P_1$

shaft material : $S_y = 310$ MPa , $S_u = 500$ MPa

$0.18\ S_u = 90$ MPa

$0.31\ S_y = 96.1$ MPa $\rightarrow \tau_{all} = 0.75 * 90 = 67.5$ MPa

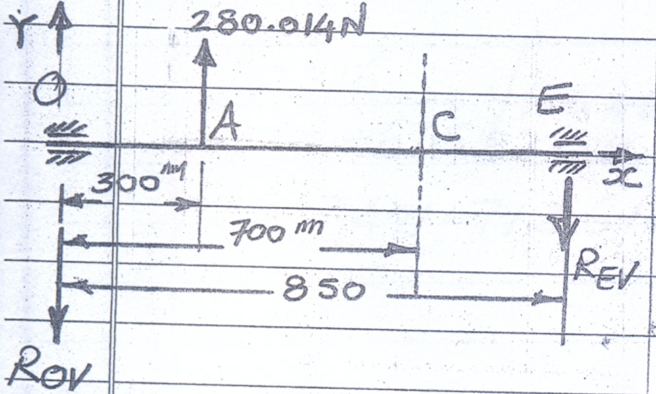
$T_A = T_C \rightarrow (P_1 - P_2)\frac{d_A}{2} = (270 - 50)(\frac{300}{2})$

$0.8\ P_1 * 250 = 220 * 300 \longrightarrow P_1 = 330\,N$ and $P_2 = 66\,N$

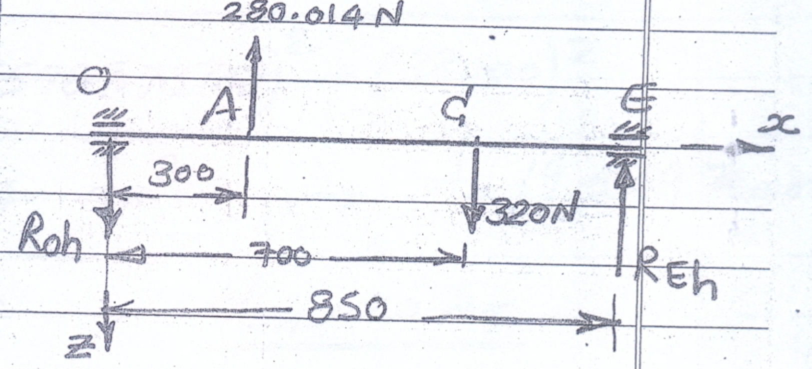
$(P_1 + P_2)\cos 45 = 280.014\,N$ (Z-x plane)

$(P_1 + P_2)\sin 45 = 280.014\,N$ (Y-x plane)

Y-x plane (vertical)



Z-x plane (Horizontal)



$\Sigma M_O = 0 : 280.014 * 300 = R_{EV} * 850$

$R_{EV} = 98.8285\,N$

$\Sigma F_y = 0 : R_{OV} = 181.1855\,N$

$\Sigma M_O = 0$

$280.014 * 300 - 320 * 700 + R_{Eh} * 850 = 0$

$R_{Eh} = 164.701\,N$

$\Sigma F_z = 0 : R_{oh} - 280.014 + 320 - 164.701 = 0$

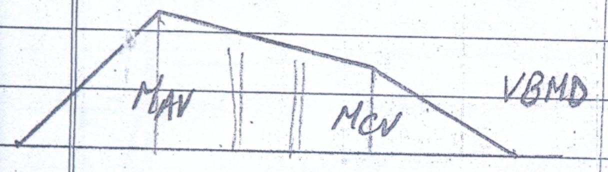
$R_{oh} = 124.715\,N$

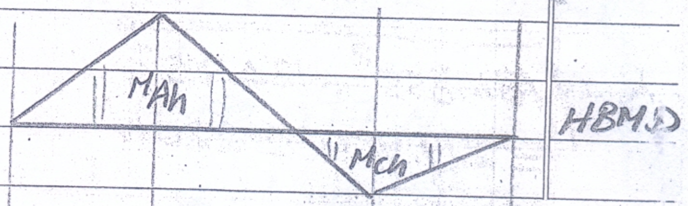
$M_{AV} = R_{OV} * 300 = 54355.65$ Nmm

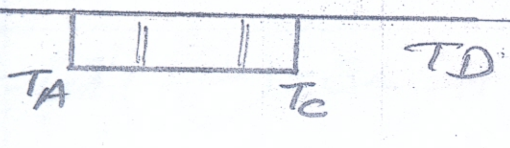
$M_{CV} = R_{EV} * 150 = 14824.275$ Nmm

$M_{Ah} = R_{oh} * 300 = 37414.5$ Nmm

$M_{Ch} = R_{Eh} * 150 = 24705.15$ Nmm







$$M_A = \sqrt{M_{Av}^2 + M_{Ah}^2} = \sqrt{(54355.65)^2 + (37414.5)^2}$$

$$= 65987.73748 \text{ Nmm}$$

$$M_C = \sqrt{M_{Cv}^2 + M_{Ch}^2} = \sqrt{(14824.275)^2 + (24705.15)^2}$$

$$= 28811.51794 \text{ Nmm}$$

Then $M_b = M_A = 65987.73748$ Nmm

$M_t = T_A = 220 * 150 = 33000$ Nmm

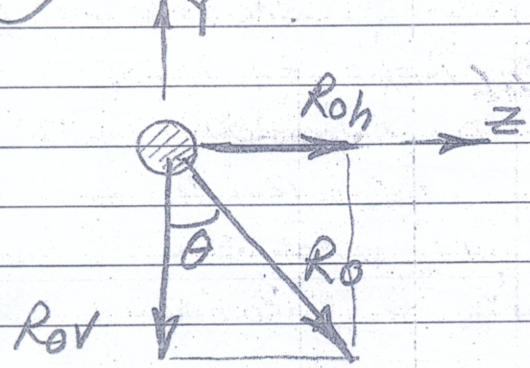
$$d^3 = \frac{16}{\pi \tau_{all}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$= \frac{16}{\pi * 67.5} \sqrt{(1.5 * 65987.73748)^2 + (33000)^2}$$

$$= 7471.713614 \text{ mm}^3 \rightarrow d = 19.5497 \text{ mm}$$

$\underline{d_{sh} = 20 \text{ mm}}$

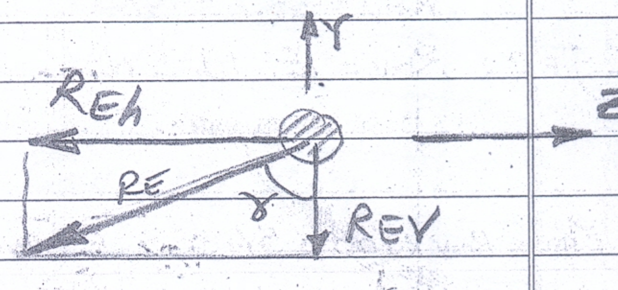
Bearing "O"



$$R_O = \sqrt{181.1855^2 + 124.715^2}$$
$$= 219.959 \simeq 220 N$$

$$\theta = \tan^{-1}\left(\frac{Roh}{Rov}\right) = 34.541$$

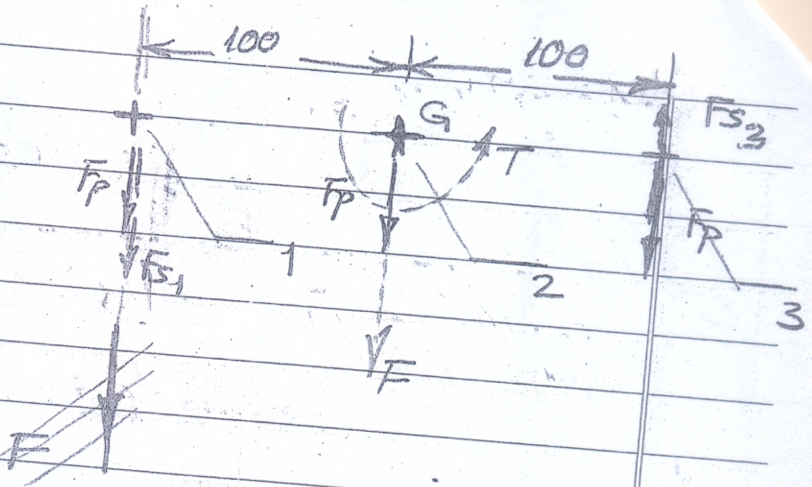
Bearing "E"



$$R_E = \sqrt{98.8285^2 + 164.701^2}$$
$$= 192.077 N$$

$$\gamma = \tan^{-1}\left(\frac{REh}{REV}\right) = 59.034°$$

Question (2)



$F = 10000\ N$

$T = 10000 * 100 = 10^6\ Nmm$

$r_1 = r_3 = 100\ mm\ ,\ r_2 = 0$

$$S = \frac{T}{\sum r^2} = \frac{10^6}{2*100^2+0}$$

$= 50\ N/mm$

Primary shearing : $F_p = \frac{F}{3} = \frac{10000}{3} = 3333.333\ N$

secondary shear : $F_{s_1} = F_{s_3} = S r_1 = 50*100 = 5000\ N$

$F_{s_2} = 0$

$R_{max} = F_p + F_{s_1} = 3333.333 + 5000 = 8333.333\ N$

1)

$$\tau_{max} = \frac{R_{max}}{2(\frac{\pi}{4} d_r^2)} = \frac{2*8333.333}{\pi d_r^2} = \frac{5305.1646}{d_r^2}\ MPa$$

$$\tau_{all} = \frac{S_y}{2(f.s.)} = \frac{400}{2*1.7} = 117.647\ MPa$$

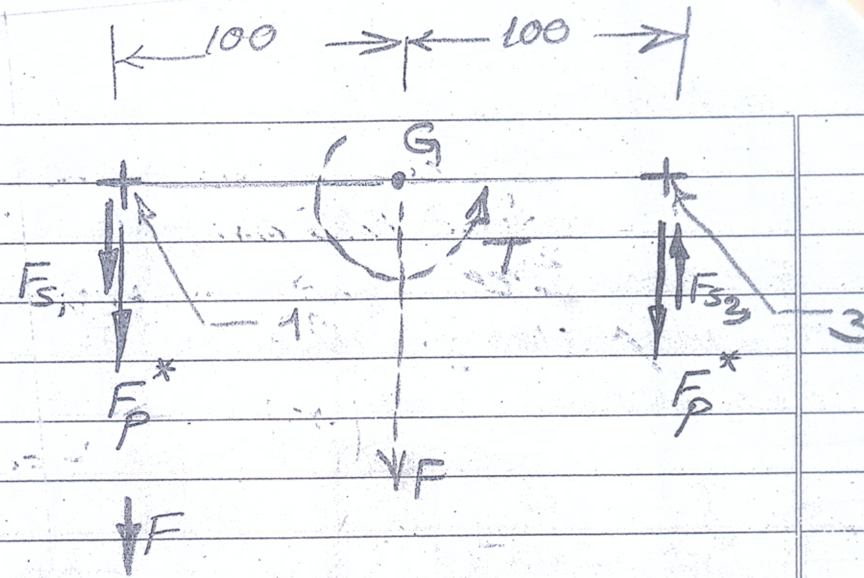
D. Eqn. : $\tau_{max} = \frac{5305.1646}{d_r^2} < \tau_{all} = 117.647$

$$d_r = \sqrt{\frac{5305.1646}{117.647}} = 6.715\ mm$$

$$d_o \simeq \frac{d_r}{0.85} = 7.9$$

$\therefore$ Select M8 , $d_o = 8\ mm$

(b)



$$F_p^* = \frac{F}{2} = 5000\ N$$

$$R_1 = F_p^* + F_{S_1} = 5000 + 5000 = 10000\ N$$

$$R_3 = 0$$

$$\tau_{bot-1} = \frac{R_1}{2\left(\frac{\pi}{4} d_r^2\right)} = \frac{10000 * 2}{\pi\,(0.85 * 8)^2}$$

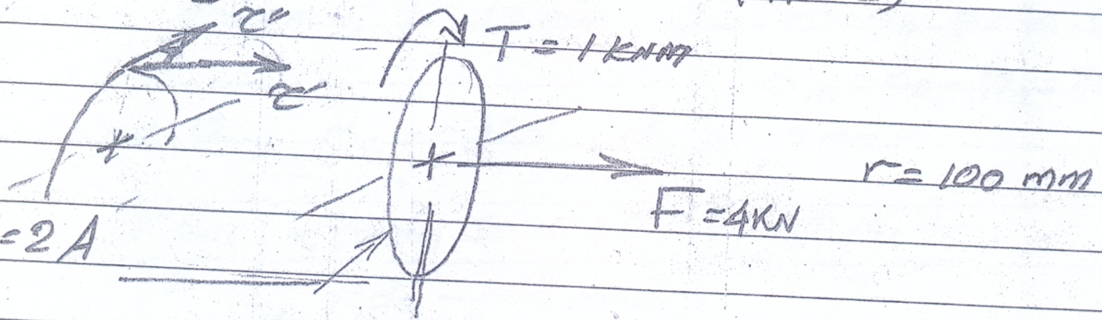
$$= 137.677\ MPa$$

$$\tau_{bolt-3} = 0$$

Question (3)

$d = 200\ mm$, $d_i = 175\ mm$

$\therefore t = \frac{d - d_i}{2} = 12.5\ mm$ $(h < t)$



$A_w = 2A$

$A = 1.414 \pi h r = 1.414 \pi \times 100\ h = 444.221\ h$

$A_w = 2A = 888.442\ h$ mm^2

$J_u = 2\pi r^3 \longrightarrow J = 0.707 h J_u$

$J_w = 2J = 1.414 \times 2\pi r^3 h = 8884424.024\ h$ mm^4

$\tau' = \frac{F}{A_w} = \frac{4000}{888.442h} = \frac{4.5}{h}$ MPa

$\tau'' = \frac{Tr}{J_w} = \frac{1 \times 10^6 \times 100}{8884424.024h} = \frac{11.256}{h}$ MPa

$\tau_{max} = \sqrt{\tau'^2 + \tau''^2} = \frac{1}{h}\sqrt{(4.5)^2 + (11.256)^2} = \frac{12.122}{h}$

$\tau_{max} \leq \tau_{all}$

$\frac{12.122}{h} \leq 100 \longrightarrow h \geq 0.12122\ mm$

let $\boxed{h = 6\ mm} \simeq \frac{t}{2}$

Question (4)

square P.S. $\rightarrow \alpha = 0$, $\cos\alpha = 1$, $\sec\alpha = 1$

$F = 60000\ N$ (screw press)

$d_o = 70\ mm$, $p = 12\ mm$ $\rightarrow d_i = d_o - p = 70 - 12 = 58\ mm$

$d_m = d_o - p/2 = 70 - 6 = 64\ mm$

$\mu = 0.12$, $\mu_c = 0.125$, $d_c = 60\ mm$

(a) $$T = \frac{F d_m}{2}\left[\frac{\pi \mu d_m \sec\alpha + l}{\pi d_m - \mu l \sec\alpha}\right] + \frac{F \mu_c d_c}{2}$$

$$= T_{nut} + T_{collar}$$

lead (l):

self locking $\mu > \tan\lambda = \dfrac{l}{\pi d_m}$

$$\therefore l < \mu \pi d_m = 0.12 \pi (64) = 24.127$$

$$\therefore l = 2p = 24\ mm$$

$$T_{nut} = \frac{60000 * 64}{2}\left[\frac{\pi * 0.12 * 64 + 24}{\pi * 64 - 0.12 * 24}\right] = 466261.827\ N.mm$$

$$T_{collar} = \frac{60000 * 0.125 * 60}{2} = 225000\ Nmm$$

$$T = 691261.827\ Nmm \Longrightarrow$$

(b) $$e_{threads} = \frac{T_o}{T_{nut}} = \frac{Fl}{2\pi T_{nut}} = \frac{60000 * 24}{2\pi * 466261.827}$$

$$= 0.491 = 49.1\% \Longrightarrow$$

$$e_{press} = \frac{T_o}{T} = \frac{Fl}{2\pi T} = \frac{60000 * 24}{2\pi * 691261.827} = 0.331$$

(c) $\sigma = \frac{F}{A} = \frac{60000}{\frac{\pi}{4}(58)^2} = 22.709$ MPa (Comp)

$\tau = \frac{Tr}{J} = \frac{16T}{\pi d_i^3} = \frac{16 * 691261.827}{\pi (58)^3} = 18.044$ MPa

$\sigma_{max} = \frac{\sigma}{2} \pm \sqrt{(\frac{\sigma}{2})^2 + \tau^2} = \frac{-22.709}{2} \pm \sqrt{(\frac{22.709}{2})^2 + 18.044^2}$

$= -11.3545 \pm 21.319$

$\sigma_{max-c} = 32.6735$ MPa

$\sigma_{max-t} = 9.9645$ MPa

$\tau_{max} = 21.319$ MPa

(d)

$\sigma_{br} = \frac{F}{\frac{\pi}{4}(d_o^2 - d_i^2)\frac{H}{P}} = \frac{4 * 12 * 60000}{\pi (70^2 - 58^2) * 240}$ ← H

$= 2.4868$ MPa →

$\boxed{\sigma_{br} = 2.49 \text{ MPa}}$

Question (5)

(a)

$$P = (F_1 - F_2)V \quad , \quad \frac{F_1 - F_c}{F_2 - F_c} = \frac{F_1 - mV^2}{F_2 - mV^2} = e^{\mu\theta}$$

$$\therefore F_1 - mV^2 = F_2 e^{\mu\theta} - mV^2 e^{\mu\theta}$$

$$F_2 e^{\mu\theta} = F_1 - mV^2(1 - e^{\mu\theta})$$

$$F_2 = \frac{F_1}{e^{\mu\theta}} + \left(\frac{e^{\mu\theta} - 1}{e^{\mu\theta}}\right) mV^2$$

$$\therefore P = \left[F_1 - \frac{F_1}{e^{\mu\theta}} - \left(\frac{e^{\mu\theta} - 1}{e^{\mu\theta}}\right) mV^2\right] V$$

$$= \left[F_1 \left(\frac{e^{\mu\theta} - 1}{e^{\mu\theta}}\right) - mV^2 \left(\frac{e^{\mu\theta} - 1}{e^{\mu\theta}}\right)\right] V$$

$$= \frac{e^{\mu\theta} - 1}{e^{\mu\theta}} \left(F_1 - mV^2\right) V$$

$$\frac{dP}{dV} = \frac{e^{\mu\theta} - 1}{e^{\mu\theta}} \left(F_1 - 3mV^2\right) = 0$$

$$3mV^2 = F_1 = \sigma_{all} A$$

$$V^2 = \frac{\sigma_{all} A}{3m} = \frac{\sigma_{all} A}{3(\rho A)} = \frac{\sigma_{all}}{3\rho}$$

$$\therefore V^* = \sqrt{\frac{\sigma_{all}}{3\rho}} \quad \Longrightarrow$$

(b) V-belt size C → $A = 230\ mm^2$

$d_1 = 240$ mm , $n_1 = 1200$ rpm $= 20$ rps

$d_2 = 400$ mm , Belt angle $40°$ → $2\beta = 38°$

$\beta = 19°$

$\rho = 1150\ Kg/m^3$ → $m = \rho A = 1150 * 230 * 10^{-6}$

$= 0.2645\ Kg/m$

$C = 1000$ mm , $\mu = 0.13$, $\sigma_{all} = 2$ MPa

Req:

Power can be transmitted

soln.

$V = \pi d_1 n_1 = \pi (0.24)(20) = 15.0796 \simeq 15.1\ m/s$

$\theta = 180 - 2\sin^{-1}\left(\frac{d_2 - d_1}{2C}\right) = 170.823° = 2.981$ rad.

$\mu_e = \frac{\mu}{\sin\beta} = \frac{0.13}{\sin(19)} = 0.3993$

$e^{\mu_e \theta} = e^{0.3993 * 2.981} = 3.288$

$F_1 = \sigma_{all} A = 2 * 230 = 460\ N$

$F_c = m V^2 = 0.2645 * (15.1)^2 = 60.309\ N$

$\frac{F_1 - F_c}{F_2 - F_c} = e^{\mu_e \theta}$ → $(460 - 60.309) = 3.288 (F_2 - 60.309)$

$F_2 = 121.561 + 60.309 = 181.87\ N$

Power $= N (F_1 - F_2) V = 3 * (460 - 181.87)(15.1)$

$= 12599.289$ Watt

Transmitted power $\simeq 12.599$ KW ⟹