① $M_a = 70\,Nm$ $\quad T_a = 40\,Nm$

$M_m = 55\,Nm$ $\quad T_m = 35\,Nm$

$\sigma_{ut} = 700\,MPa$

$\sigma_y = 560\,MPa$

$\sigma_{nm} = \frac{M_1}{I} = \frac{32M}{\pi d^3}$ $\quad \sigma_{xy} = \tau_{xy} = \frac{16T}{\pi d^3}$

$\sigma_e = 210\,MPa$

$\sigma_m = \left(4k_f^2 \sigma_{nm}^2 + 3k_{fs}^2 \sigma_{xym}^2\right)^{1/2}$

$= \frac{16}{\pi d^3}\left(292^2 + 3(63)^2\right)^{1/2} = \frac{16}{\pi d^3}(265.46)$

$\sigma_a = \frac{16}{\pi a^3}\left(4k_f^2 M_1^2 + 3d^4 a\right)^{1/2}$

$= \frac{16}{\pi a^3}(338.45)$

$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{\sigma_{ut}} = \frac{1}{n} \Rightarrow \frac{16}{\pi a^3}\left(\frac{338.45}{210} + \frac{265.46}{700}\right) = \frac{1}{2}$

$d_m = 27.3\,mm$

$\sigma_{nm\,max} = \frac{32}{\pi d^3}(k_f M_m + k_f M_1) = 133.44\,MPa$

$\sigma_{xy} = \frac{16}{\pi a^3}(k_{fs} T_m + k_{fs} T_a) = 36\,kPa$

$\left(\sigma_{nm}^2 + 3\tau_{xym}^2\right)^{1/2} = 3\sigma_{nm\,max} < \sigma_y$

No yielding

(2) $\sigma_{ut} = 1200\ MPa$ $M_a = 87.5\ N\cdot mm$ $T_a = 0$

$\sigma_y = 900\ MPa$ $M_m = 0$ $T_m = 45.2\ Nm$

$\frac{d'}{D} = \frac{d}{D} - \frac{2r}{D} = 0.65$ $\frac{r}{d'} = \frac{r}{\frac{D}{D}\,d'} = 0.07$

$\sigma_{xa} = \frac{32 k_f M_a}{\pi d^3} = \frac{16}{\pi d^3}(0.189)$ $\sigma_{ya} = 0$

$\sigma_{xm} = 0$ $\sigma_{ym} = \frac{16 k_f (0.094)}{\pi d^3}$

$\sigma_a = \frac{16}{\pi d^3}(0.189)$ $\sigma_m = \frac{16}{\pi d^3}(0.094)$

$\sigma_{xa} = \sigma_{xa}$ $\sigma_{xym} = \sigma_{ym}$

$\left(\sigma_{xa}^2 + 3\sigma_{xym}^2\right)^{1/2} < \sigma_y$ No yielding

(3) $\sigma_e = 280\ MPa$

a) B $\exists$ R_{By} R_{Bz}

$\Sigma T_x = 0 \Rightarrow T_A = F\cos 20^\circ \frac{D}{2}$

$F = 4.82\ kN$

$\Sigma M_{By} = 0 \Rightarrow R_{cy}(250) + F\cos 20(55)^\circ = 0$

$R_{cy} = -6.34\ kN$

$\Sigma F_y = 0 \Rightarrow R_{By} = 1.81\ kN$

$\Sigma F_z = 0$ $-R_{Bz} = -0.66\ kN$

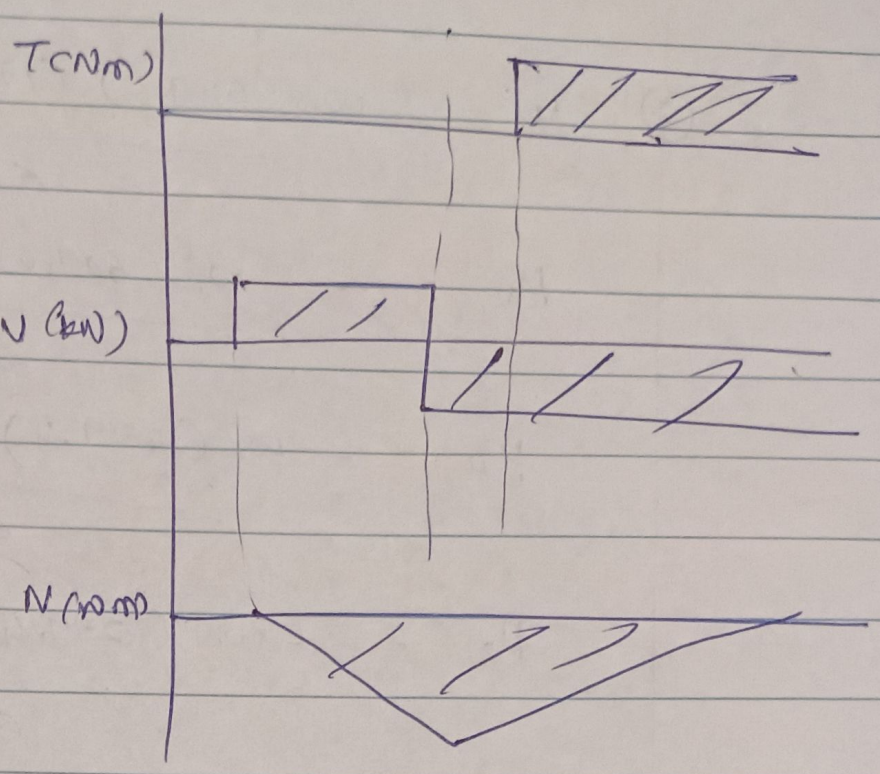
a) $\sigma_{xa\,max} = \frac{16}{\pi d^3}(2603)$ $\left[(\sigma_{xx})^2 + 3(\sigma_{xyx})^2\right]^{1/2}$

$\sigma_{xym\,max} = \frac{16}{\pi d^3}\,748$ $= \frac{16}{\pi d^3}(2900) \le \frac{\sigma_y}{2}$

b) $\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{\sigma_{ut}} = \frac{1}{n} \Rightarrow \frac{16}{\pi d^3}\left(\frac{2603}{280} + \frac{1296}{500}\right) = \frac{1}{2.1}$

$d_m = 52.88\ mm$

(4)



$M_a = 491.66$ Nm

$M_m = 0$

$T_a = 0$

$T_m = 107$ Nm

$\sigma_{xa} = 117.0$ MPa

$\sigma_{xym} = 17.95$ Mpa

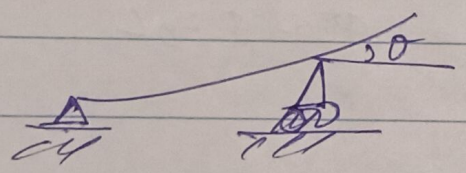
$\sigma_{ult} = 420$ MPa

$\sigma_e = 210$ MPa

$$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{\sigma_{ult}} = 0.83 = \frac{1}{n}$$

$$n = 1.58$$

$\sigma_{eq} < \sigma_y \Rightarrow$ No yeilding



$$\mu = \frac{-P\mu x}{\sigma EL}(x^2 - b^2 - x^2)$$

slope @ K $\leq 5 \times 10^{-4}$ rad

@ A $\leq 10^{-3}$ rad

@ K = slope @ B

$\theta(0) = \leq 5 \times 10^{-4})$

(3) $M_1 = -\omega_1^2 (609.6)(177.5)(787.4^2 - 609.6^2 - 177.5^2)$ / $6EIL$

$M_{12} = -\omega_1^2 (609.6)(508)(787.4^2 - 609.6^2 - 508^2)$ / $6EIL$

$M_{21} = -\omega_1^2 (279.4)(177.5)(787.4^2 - 279.4^2 - 177.5^2)$ / $6EIL$

$M_{22} = -\omega_1^2 (279.4)(508)(787.4^2 - 279.4^2 - 508^2)$ / $6EIL$

$M_1 = \frac{-3.66}{6EIL}$ $M_{12} = \frac{0.47}{6EIL}$ $M_{21} = \frac{-0.2}{6EIL}$ $M_2 = \frac{3.36}{6EIL}$

$M_1 = M_{11} + M_{21} = \frac{-9.56}{6EIL}$ $M_2 = \frac{-9.36}{6EIL}$

$\omega_1^2 = \frac{9.8 m_i \delta_i}{\sum m_i \delta_i^2} = 0.62 \frac{EI}{mL}$

$E = 210 GMPa$

$I = \frac{\pi d^3}{64} = 804 mm^3$

$\omega_1^2 = 210 \times 0.62 \times 804 \times 10 \times 787.4 \times 10^9$

$\omega_1 = 9 GHz$