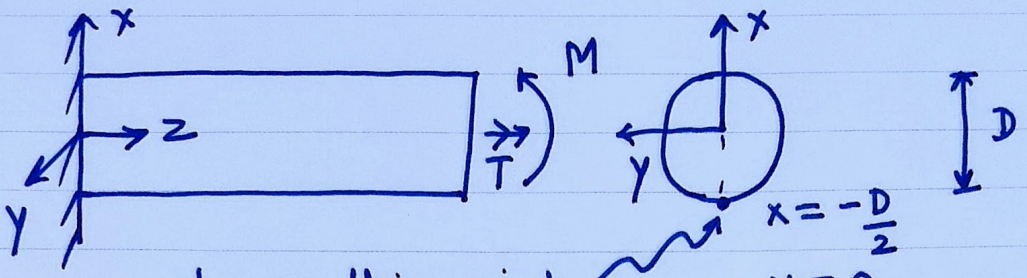
1.



choose this point — worst case scenario

Bending $\sigma_{zz} = -\frac{Mx}{I} = \frac{32M}{\pi D^3}$, $I = \frac{J}{2}$

Torsion $\sigma_{xz} = -G\alpha y = 0$, $\sigma_{yz} = +G\alpha x = -\frac{16T}{\pi D^3}$

$\sigma_{yy} = 0$ locally yz plane 2D stress

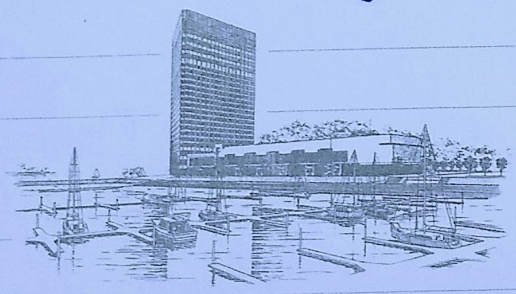
$$\sigma_{\text{normal}}^{\max} = \frac{\sigma_{zz}+\sigma_{yy}}{2} + \sqrt{\left(\frac{\sigma_{zz}-\sigma_{yy}}{2}\right)^2 + \sigma_{zy}^2}$$

$= \sigma_Y$ max normal stress theory

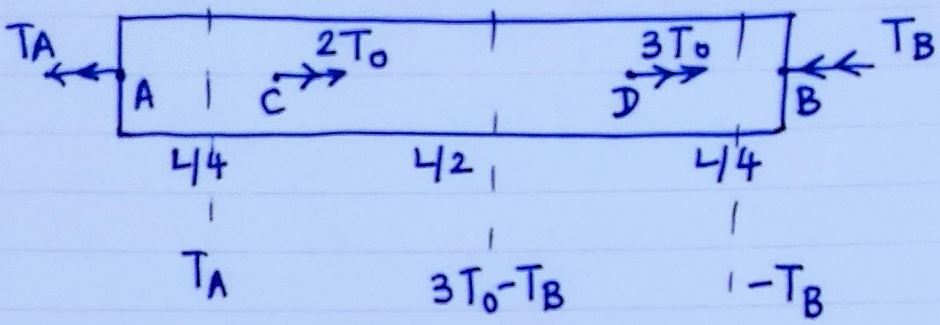
Plug in $M = 4000 \times 10^3$ Nmm, $T = 2000 \times 10$ Nmm
$\sigma_Y = 500\ N/mm^2$ to get
$D = 44.191$ mm

$$\sigma_{\text{shear}}^{\max} = \sqrt{\left(\frac{\sigma_{zz}-\sigma_{yy}}{2}\right)^2 + \sigma_{zy}^2} = \frac{\sigma_Y}{2}$$ max shear stress theory

Plug in given values to get
$D = 44.997$ mm
In practice, choose
$D = \max(44.191, 44.997)$
$\simeq$ 45mm dia shaft



2.



Torque Balance $\Rightarrow$ $T_A + T_B = 5T_0 \Rightarrow T_A = 5T_0 - T_B$

Total angular deflection = 0

$$\Rightarrow \underbrace{\frac{(5T_0 - T_B)}{GJ}\frac{L}{4}}_{\theta_{CA}} + \underbrace{\frac{(3T_0 - T_B)}{GJ}\frac{L}{2}}_{\theta_{DC}} + \underbrace{\frac{(-T_B)}{GJ}\frac{L}{4}}_{\theta_{BD}} = 0$$

$\theta_{XY} \equiv \theta$ @ X wrt Y $= \theta_X - \theta_Y$

solve $T_B = 11T_0/4$, $T_A = 5T_0 - T_B = 9T_0/4$

$$\theta_{CA} = \frac{(5T_0 - T_B)}{GJ}\frac{L}{4} = \frac{9}{16}\frac{T_0 L}{GJ} = \theta_C$$

$$\theta_{DC} = \frac{(3T_0 - T_B)}{GJ}\frac{L}{2} = \frac{T_0 L}{8GJ}$$

$$\theta_{DA} = \left(\frac{9}{16} + \frac{1}{8}\right)\frac{T_0 L}{GJ} = \frac{11 T_0 L}{16 GJ}$$