12 Stress components due to the basic loads are:-

direct tension (uniform)

$\sigma_d = P/A = 120*10^3/\frac{\pi}{4}*50^2 = 61$ MPa

direct shear (parabolic, max. at centre (z=0))

$\hat{\tau}_d = \frac{4}{3}V/A = \frac{4}{3}*120*10^3/\frac{\pi}{4}*50^2 = 81$ MPa

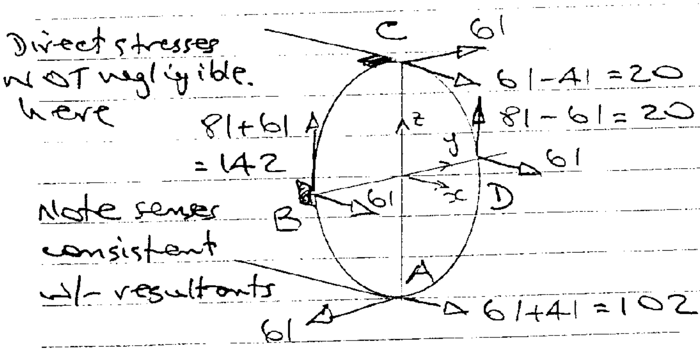
bending normal (linear, max at $z = \pm D/2$)

$\hat{\sigma}_b = M\hat{y}/I = 500*10^3*32/\pi*50^3 = 41$ MPa

torsional shear (linear, max at outer surface)

$\hat{\tau}_t = T\hat{r}/J = 1500*10^3*16/\pi*50^3 = 61$ MPa

Examine X-section to ascertain potential critical element(s) - sketch is really essential.




Evidently elements A & B are most severely loaded - by inspection of sketch ($C < A$ & $D < B$)

Use max shear stress theory say (or distortion energy)

(Common mistake - inadequate search)

at A $\quad \sigma_x = 102 \quad \sigma_y = 0 \quad \tau_{xy} = -61 \quad (\sigma_z = 0)$.

$\therefore \bar{\sigma} = 51 \quad \tilde{\sigma} = \sqrt{(51^2 + 61^2)} = 80$ MPa

$\sigma_e = \hat{\sigma} - \check{\sigma} = (\bar{\sigma} + \tilde{\sigma}) - (\bar{\sigma} - \tilde{\sigma}) = 2\tilde{\sigma}$

$= 159$ MPa

[Note $\sigma = 102$ & $\tau = 142$ do NOT occur simultaneously]

at B $\quad \sigma_x = 61 \quad \sigma_z = 0 \quad \tau_{xz} = 142 \quad (\sigma_y = 0)$

$\therefore \bar{\sigma} = 31 \quad \tilde{\sigma} = \sqrt{(31^2 + 142^2)} = 146$

$\sigma_e = 2\tilde{\sigma} = 292$ MPa.

So max $\sigma_e$ at x-section is **292** MPa