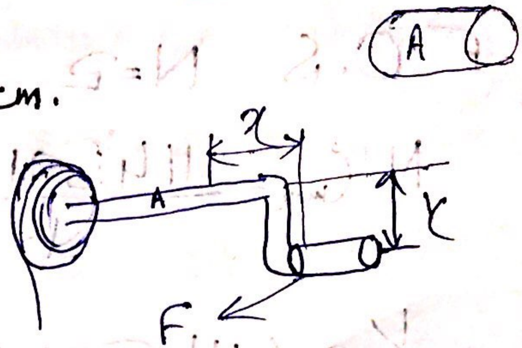
Q1) Given Data:

F = 15067 N, EL = 207,000 KPa,

E = 223×10⁶ KPa, ~~[illegible]~~ n = 0

N = 1, FOS = 1, Y = 15;

Dimensions X = 20 cm.



Sol: The moment at section A is $M = 45000 \times 0.2 = 9000\ Nm$

& the torque on the shaft is

$T = 45000 \times 0.15 = 6750\ Nm.$

The normal stress due to M at A is:

$$\sigma = -\frac{64Md}{2\pi d^4} = -\frac{32M}{\pi d^3}$$

& the maximum shear stress due to T at A is.

$$\tau = \frac{32Td}{2\pi d^4} = \frac{16T}{\pi d^3}$$

The shear stress due to shear force F is zero at A.

$$\sigma_{1,3} = \tfrac{1}{2}\sigma \pm \tfrac{1}{2}(\sigma^2 + 4\tau^2)^{1/2}, \quad \sigma_2 = 0$$

i) Max shear stress theory

$$\tau_{max} = \tfrac{1}{2}(\sigma_1 - \sigma_3)$$

$$= \tfrac{1}{2}(\sigma^2 + 4\tau^2)^{1/2}$$

$= \frac{1}{2} \frac{32}{\pi d^3} (M^2 + T^2)^{1/2}$

$= \frac{16}{\pi d^3} (9000^2 + 6750^2)^{1/2}$

$= \frac{57295.8}{d^3}$ Pa.

F.O.S N=2 the value of τ_{max} becomes

$N\tau_{max} = \frac{114591.6}{d^3}$ Pa

$\frac{1}{d^3}(114591.6) = \sigma_y/2 = \frac{207}{2} \times 10^6$

$\therefore \quad d^3 = 1107 \times 10^{-6}\ m^3$

or $\quad d = 10.35 \times 10^{-2} m = 10.4 cm.$

ii) Octahedral Shear Stress Theory.

$\tau_{oct} = \frac{1}{3}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2}$

width $\sigma_2 = 0$

$\tau_{oct} = \frac{1}{3}\left[2\sigma_1^2 + 2\sigma_3^2 - 2\sigma_1\sigma_3\right]^{1/2}$

substituting & simplifying

$\tau_{oct} = \frac{\sqrt{2}}{3}(\sigma^2 + 3\tau^2)^{1/2}$

$= \frac{\sqrt{2}}{3\pi d^3}\left[(32M)^2 + 3(16T)^2\right]^{1/2}$

$= \frac{16\sqrt{2}}{3\pi d^3}(4M^2 + 3T^2)^{1/2}$

$$= \frac{16\sqrt{2}}{3\pi d^3}\left[4(9000)^2 + 3(6750)^2\right]^{1/2}$$

$$= \frac{\sqrt{2}}{3\pi d^3} \times 343418$$

equating this to Octahedral shear stress at yeilding of a uniaxial ~~stress~~ tension bar using FOS $n = 2$.

$$\frac{\sqrt{2}}{3\pi d^3} \times 2 \times 343418 = \frac{\sqrt{2}}{3} \cdot \delta_y .$$

or $2 \times 343418 = \pi d^3 \delta_y = \pi d^3 \times 207 \times 10^6$

$\therefore d^3 = 1.056 \times 10^{-3}$

or $d = 0.1018 m = 10.18 cm$.

Q2:- Given data:-

⇒ In figure the rigid bar BDE is supported by two links AB & CD.

⇒ Link AB is made of aluminum ($E = 70$ GPa) and has a cross-sectional area of $5 mm^2$. ⇒ Link CD is made of steel ($E = 200$ GPa) and has a cross-sectional area of ($60 mm^2$).

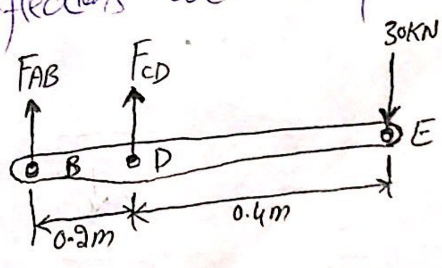
⇒ For The first Two digits of R - KN force. Determine the deflection a) of B, b) of D, and c) of E.

Solution:- * Apply a free-body analysis to the bar BDE to find the forces exerted by links AB & DC.

* Evaluate the deformation of links AB and DC or the displacements of B and D.

* Workout the geometry to find the deflection at E given the deflections at B & D.

FREE-BODY:- Bar BDE



$$\sum M_B = 0$$

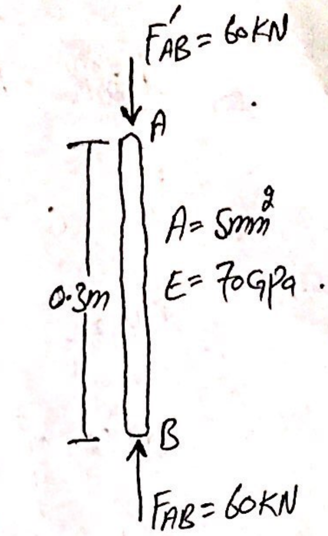
$$0 = (30KN \times 0.6m) + F_{CD} \times 0.2m$$

$$\boxed{F_{CD} = +90KN \text{ Tension}}$$

$\sum M_D = 0$

$0 = -(30KN \times 0.4m) - F_{AB} \times 0.2m$

$\boxed{F_{AB} = -60KN \text{ compression}}$

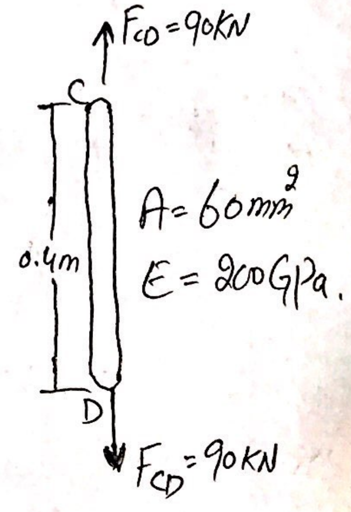


Displacement of B:-

$$\delta_B = \frac{PL}{AE}$$

$$= \frac{(-60 \times 10^3 N)(0.3m)}{(5 \times 10^{-6} m^2)(70 \times 10^9 Pa)}$$

$$\boxed{\delta_B = 0.514mm \uparrow}$$



Displacement of D:-

$$\delta_D = \frac{PL}{AE}$$

$$= \frac{(90 \times 10^3 N)(0.4m)}{(600 \times 10^{-6} m^2)(200 \times 10^9 Pa)}$$

$$\delta_D = 300 \times 10^{-6} m$$

$$\boxed{\delta_D = 0.300mm \downarrow}$$

$$\frac{BB'}{DD'} = \frac{BH}{HD}$$

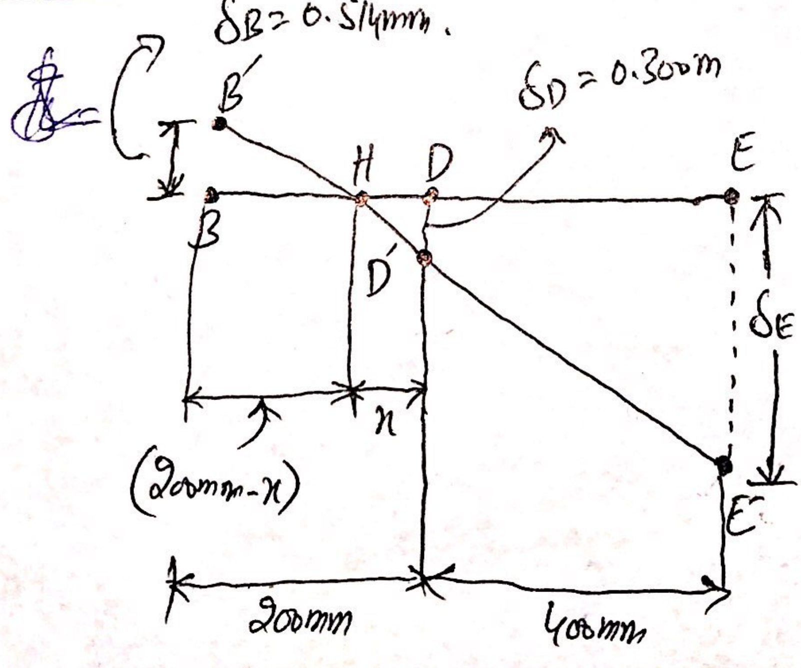
$$\frac{0.514\,mm}{0.300\,mm} = \frac{(200\,mm) - x}{x}$$

$$x = 73.7\,mm.$$

$$\frac{EE'}{DD'} = \frac{HE}{HD}$$

$$\frac{\delta_E}{0.300\,mm} = \frac{(400 + 73.7)\,mm}{73.7\,mm.}$$

$$\boxed{\delta_E = 1.928\,mm \downarrow}$$



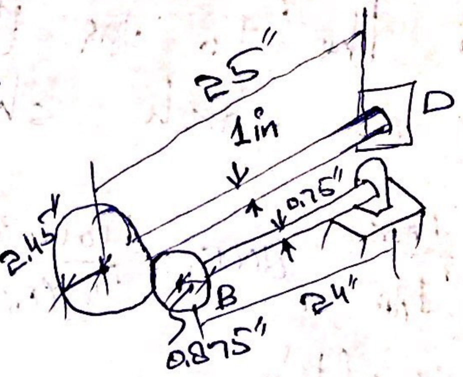
Q3) Two solid steel shaft are connected by gears.

Given Data:

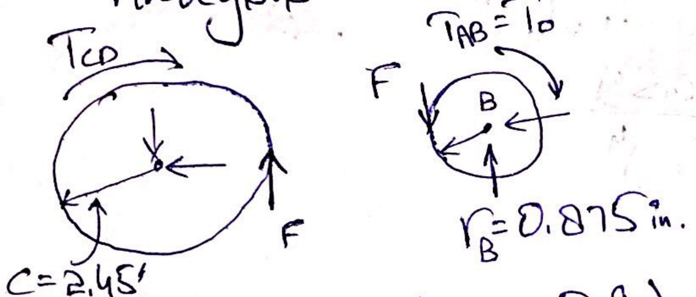
$G = 15 \times 10^6$ psi, $\tau_{all} = 10$ ksi

Dimensions $x = 15 + 10 = 25$

Required: $T_0 = ?$, $L = ?$



Sol: Static Equilibrium Analysis.

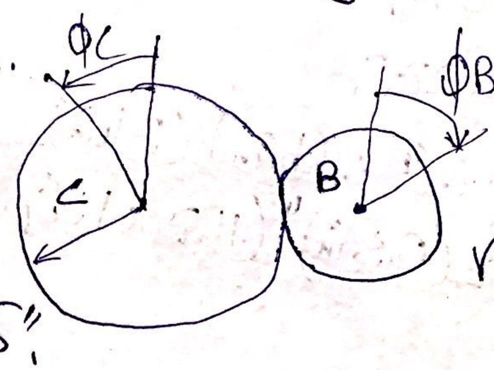


$\sum M_B = 0 = F(0.875\text{ in}) - T_0$

$\sum M_C = 0 = F(2.45\text{ in}) - T_{CD}$

$T_{CD} = 2.8\, T_0$

Apply Kinematic Analysis to relate angular rotations.



$r_B = 0.875"$

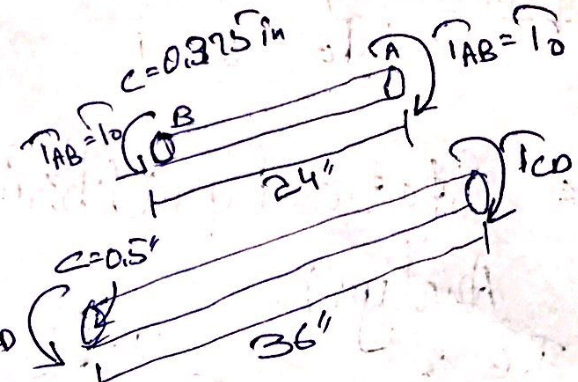
$r_C = 2.45"$

$$r_B \phi_B = r_C \phi_C$$

$$\phi_B = \frac{r_C}{r_B}\phi_C = \frac{2.45\,in}{0.875\,in}\phi_C$$

$$\phi_B = 2.8\,\phi_C.$$

Find the T_0 for the maximum allowable torque ~~...~~ on each shaft.



$$\tau_{max} = \frac{T_{AB}c}{J_{AB}} \quad 8000\,psi = \frac{T_0(0.375")}{\frac{\pi}{2}(0.375")^4}$$

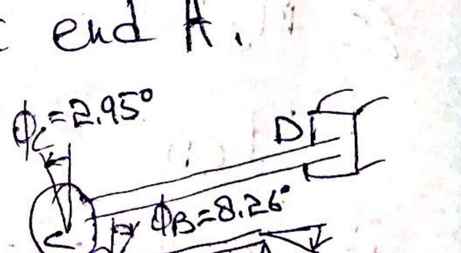
$$T_0 = 663\,lb.in.$$

$$\tau_{max} = \frac{T_{CD}c}{J_{CD}} \quad 8000\,psi = \frac{2.8T_0(0.5")}{\frac{\pi}{2}(0.5")^4}$$

$$T_0 = 561\,lb.in$$

$$\boxed{T_0 = 561\,lb.in}$$

Find the corresponding angle of twist for each shaft & the net angular rotation of end A.



$$\phi_{A/B} = \frac{T_{AB}L}{J_{AB}G} = \frac{(561\,lb.in)(24\,in)}{\frac{\pi}{2}(0.375\,in)^4(11.2\times10^6\,psi)}$$

$$= 0.387\,rad = 2.22°.$$

$$\phi_{C/D} = \frac{T_{CD}L}{J_{CD}G} = \frac{2.8(561\,lb.in)(24\,in)}{\frac{\pi}{2}(0.5\,in)^4(11.2\times10^6\,psi)}$$

$= 0.514 \, rad = 2.95°$.

$\phi_B = 2.8 \, \phi_C = 2.8 \, (2.95°) = 8.26°$

$\phi_A = \phi_B + \phi_{A/B} = 8.26° + 2.22°$

$$\boxed{\phi_A = 10.48°}$$

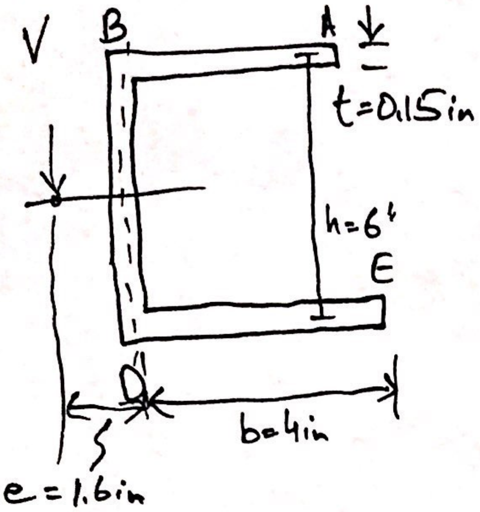
Scanned with CamScanner

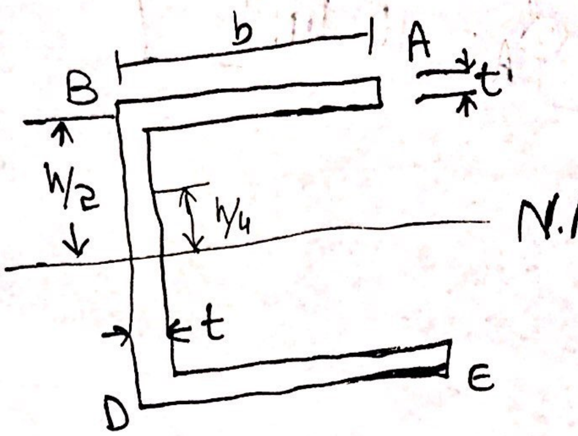
Q4) Determine the location for the shear center of the channel section.

Given Data:

$b = 4\,in$, $h = 6\,in$, $t = 0.15\,in$

$V = 159$ kips.





Sol: Shear stress distribution for

$V = 159\,k$,

$$\tau = q/t = \frac{VQ}{It}$$

Shearing stresses in the flanges

$$\tau = \frac{VQ}{It} = \frac{V}{It}(st)\,h/2 = \frac{Vh}{2I}s.$$

$$\tau_B = \frac{Vhb}{2\left(\frac{1}{12}th^2\right)(6b+h)} = \frac{6Vb}{th(6b+h)}$$

$$= \frac{6(2.5\,kips)(4\,in)}{(0.15\,in)(6\,in)(6\times4+6\,in)}$$

$$\tau_B = 2.22\,ksi.$$

Shearing stress in the web.

$$\tau_{max} = \frac{VQ}{It} = \frac{V(\frac{1}{8}ht)(4b+h)}{\frac{1}{12}th^2(6b+h)t}$$

$$= \frac{3V(4b+h)}{2th(6b+h)}$$

$$= \frac{3(159k)(4\times4in+6in)}{2(0.15in)(6in)(6\times6in+6in)}$$

$$= 4.06 \text{ ksi}$$

Q5: Given data:-

⇒ grade of steel used $\sigma_{all} = 15ksi + 4ksi = 19ksi$

⇒ and $\tau_{all} = 15ksi + 1ksi = 16ksi$

⇒ select the wide-flange beam which should be used.

~~Solution: Requirements~~

Solution:- * Determine reactions at "A" & "D".

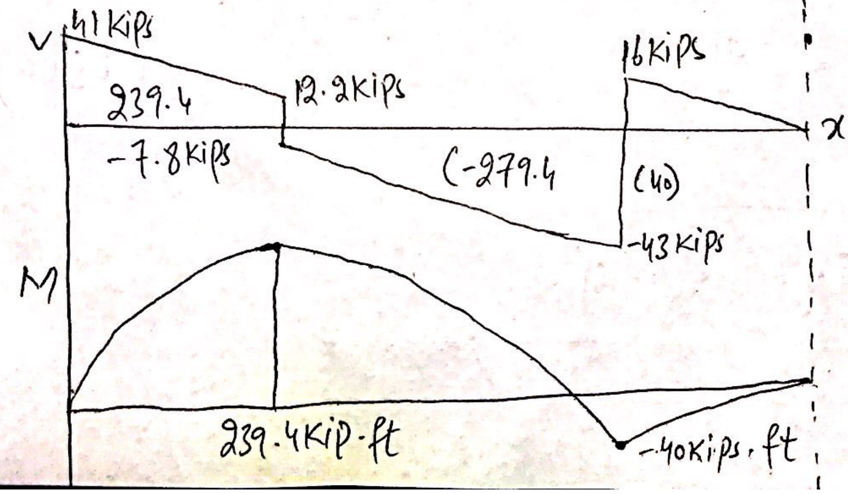
$\Sigma M_A = 0 \rightarrow R_D = 59$ Kips

$\Sigma M_D = 0 \rightarrow R_A = 41$ kips

* Determine maximum shear and bending moment from shear and bending moment diagrams.

$|M|_{Max} = 239.4$ Kip.in with $V = 12.2$ Kips

$|V|_{max} = 43$ Kips.



* Calculate required section modulus and select appropriate beam section.

$$S_{min} = \frac{|M|_{max}}{\sigma_{all}} = \frac{24 \text{ kips.in}}{24 \text{ ksi}} = 119.7 \text{ in}^3$$

Select $W_{21} \times 62$ beam section

* Find maximum shearing stress, Assuming uniform shearing stress in web,

$$\tau_{max} = \frac{V_{max}}{A_{web}} = \frac{43 \text{ kips}}{8.40 \text{ in}^2} = 5.12 \text{ ksi} < 14.5 \text{ ksi}$$

* Find maximum normal stress.

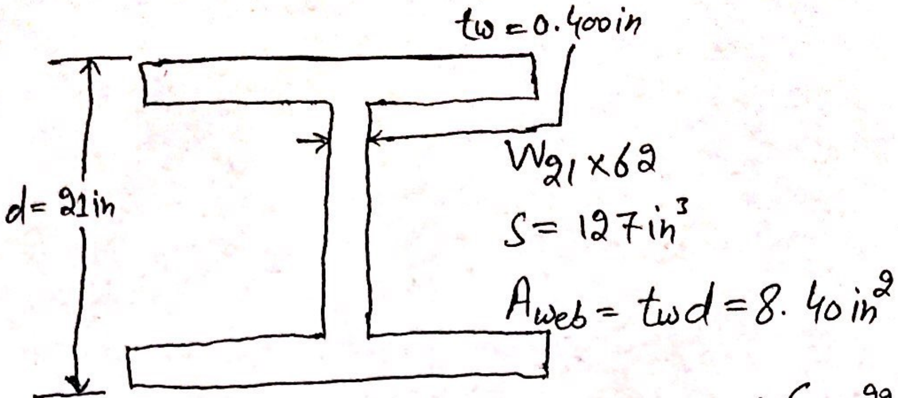
$$\sigma_a = \frac{M_{max}}{S} = \frac{2873 \ 60 \text{ kip.in}}{127 \text{ in}^3} = 22.6 \text{ ksi}$$

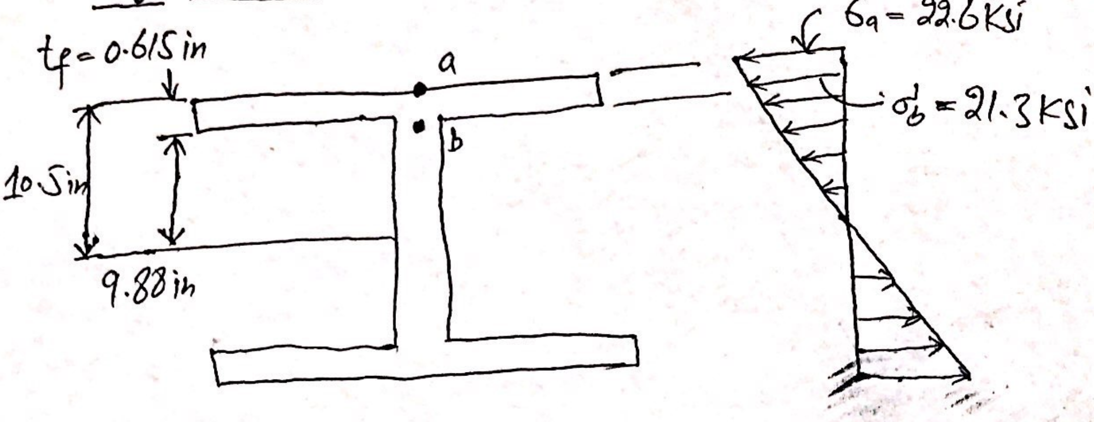
$$\sigma_b = \sigma_a \frac{y_b}{c} = (22.6 \text{ ksi}) \frac{9.88}{10.5} = 21.3 \text{ ksi}$$

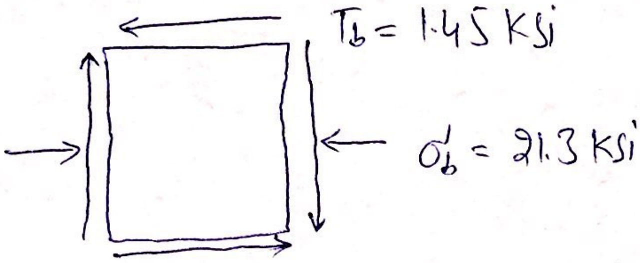
$$\tau_b = \frac{V}{A_{web}} = \frac{12.2 \text{ kips}}{8.40 \text{ in}^2} = 1.45 \text{ ksi}$$

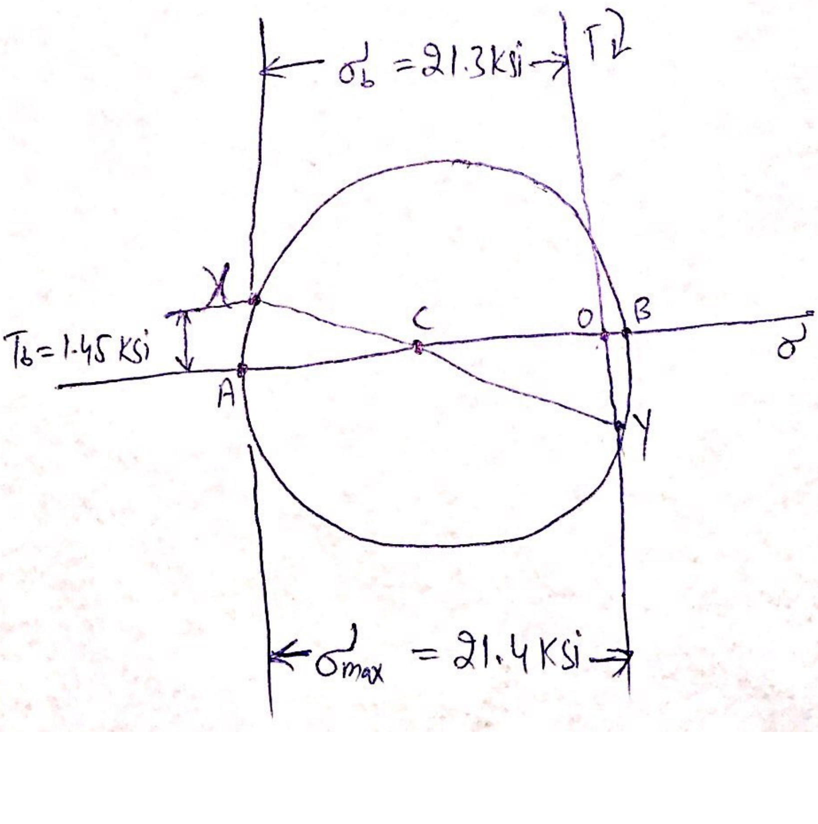
$$\sigma_{max} = \frac{21.3 \text{ ksi}}{2} + \sqrt{\left(\frac{21.3 \text{ ksi}}{2}\right)^2 + (1.45 \text{ ksi})^2}$$

$$\boxed{\sigma_{max} = 21.4 \text{ ksi} < 24 \text{ ksi}}$$


tw = 0.400 in
d = 21 in
W21 x 62
S = 127 in³
A_web = twd = 8.40 in²


tf = 0.615 in
a
b
10.5 in
9.88 in
σa = 22.6 ksi
σb' = 21.3 ksi


τb = 1.45 ksi
σb' = 21.3 ksi


σb' = 21.3 ksi
τ
X
C
O
B
τb = 1.45 ksi
A
Y
σ
σmax = 21.4 ksi