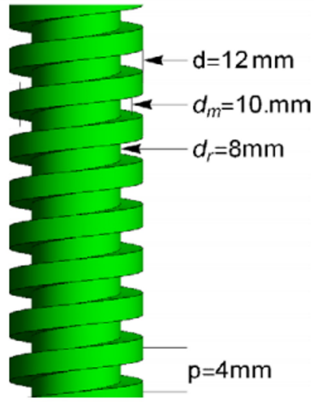
Design Problem 2

Sunday, December 13, 2020 1:13 PM

"I pledge my honor I have abided by the Stevens Honor system."

- Alex Daskins

1. Consider the design of a power screw mechanism. Power screws function by transferring rotation to linear motion. The shaft spins and a carriage moves up and down. Several relations are needed for the full design, but a simplified design can be based on the root diameter, d_r, of the shaft using the following relations. The coefficient of friction, μ, is equal to 0.1 for this material combination. The dimensions for the square thread power screw are pictured to the right. Note that this screw has a single thread and that the pitch, p, is the distance the load travels for one full rotation of the screw.



[Link to GIF showing the function of a power screw]

The torque, T, needed to apply a load, F

$$T = \frac{F d_m}{2}\left(\frac{\mu\,\pi\,d_m + p}{\pi\,d_m - \mu\,p}\right)$$

Show your answers for a-c by first using only variables without plugging in values for dimensions

a. Determine the normal stress due to the applied axial load, F, assuming the load is taken at the root diameter, d_r.

$$\boxed{\sigma = \frac{L}{A} = \frac{F}{\frac{\pi}{4}(d_r)^2}}$$

b. Determine the shear stress as a function of the torsion, T, assuming that the load is taken at the root diameter, d_r.

$$\tau = \frac{T\rho}{J} = \frac{T(R)}{\frac{\pi}{2}(R)^4} = \frac{T\left(\frac{d_r}{2}\right)}{\frac{\pi}{2}\left(\frac{d_r^4}{16}\right)} \qquad \boxed{\tau = \frac{T}{\frac{\pi}{16}(d_r)^3}}$$

c. Take the result from part b and determine the shear stress as a function of the applied load, F, using the relation provided above.

$$T = \frac{F d_m}{2}\left(\frac{\mu\pi d_m + p}{\pi d_m - \mu p}\right)$$

$$\tau = \frac{\frac{F d_m}{2}\left(\frac{\mu\pi d_m + p}{\pi d_m - \mu p}\right)}{\frac{\pi}{16}(d_r)^3} \qquad \boxed{\tau = \frac{8 F d_m\left(\frac{\mu\pi d_m + p}{\pi d_m - \mu p}\right)}{\pi (d_r)^3}}$$

For parts d-g use a load of 5kN for F

d. Determine the numerical values for stresses in Parts A and C above.

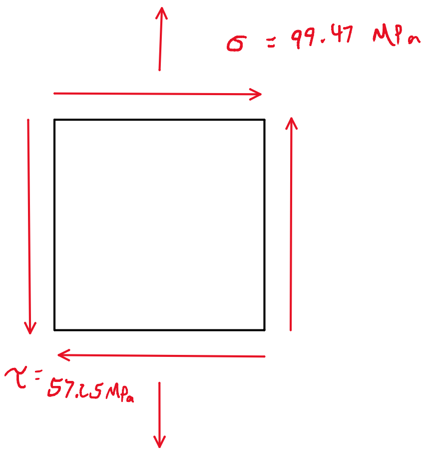
$$\sigma = \frac{F}{\frac{\pi}{4}(d_r)^2} = \frac{5000}{\frac{\pi}{4}(8\times10^{-3})^2} = \boxed{9.947\times10^{7}\ \frac{N}{m^2}} \qquad \frac{N}{m^2} = Pa \qquad \frac{N}{mm^2} = MPa$$

$$\tau = \frac{8 F d_m\left(\frac{\mu\pi d_m + p}{\pi d_m - \mu p}\right)}{\pi (d_r)^3} = \frac{8(5000)(10)\left(\frac{(.1)\pi(10)+4}{10\pi - (.1)(4)}\right)}{\pi(8)^3} = \boxed{57.25\ \frac{N}{mm^2}}$$

$$\tau = \frac{8\,T_m\left(\frac{\ldots}{\pi d_m - \mu p}\right)}{\pi (d_r)^3} = \frac{8(5000)(10)\left(\frac{\ldots}{10\pi - (.1)(4)}\right)}{\pi(8)^3} = \boxed{57.25\ \frac{N}{mm^2}}$$

e. Draw the 2D planar stress element on the surface at the root diameter showing the calculation of the actual stresses.

Hint: this stress element should be on the cylindrical surface at the root diameter



f. Determine the maximum principal stress and maximum shear stress using the Mohr Circle

$49.73 - 75.84 \approx 26$ MPa

$49.73 + 75.84 \approx 126$ MPa

$A(\sigma_x, \tau_{xy})$; $B(0, -57.25)$

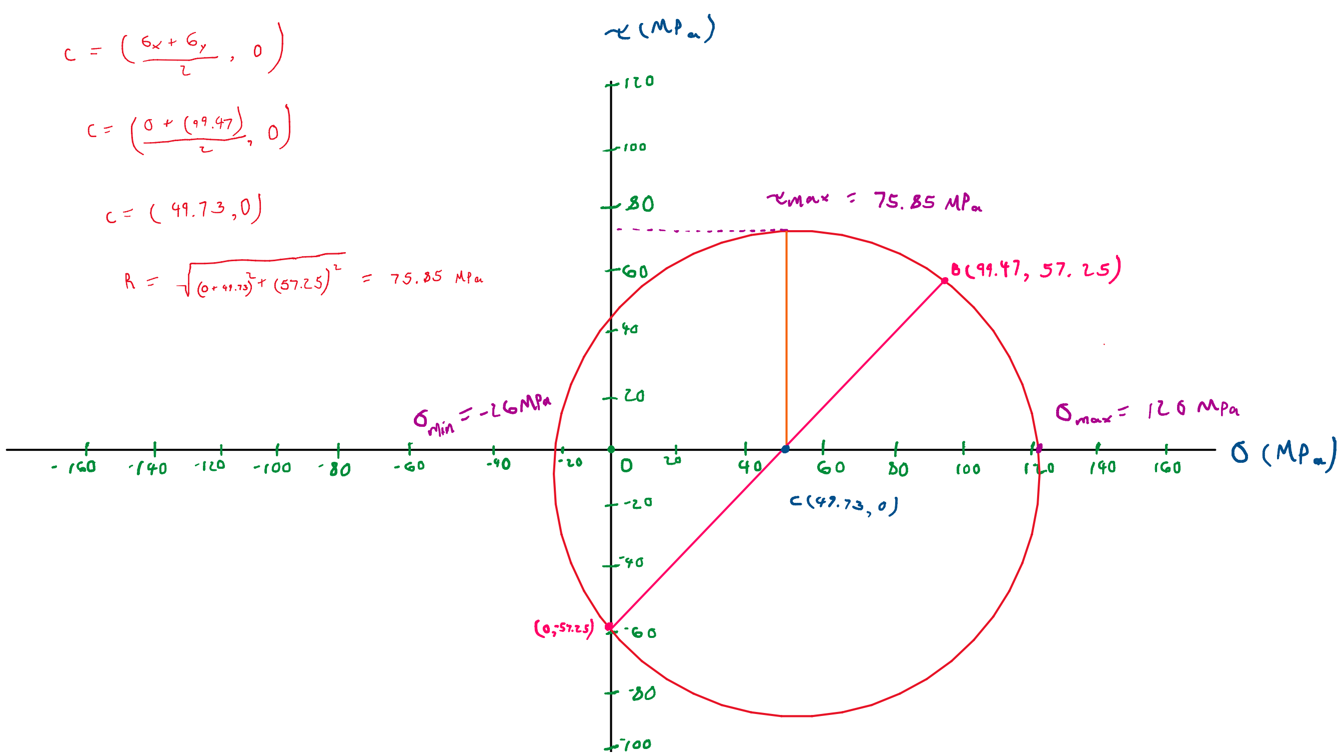
$B(\sigma_y ; \tau_{xy})$; $B(99.47, 57.25)$

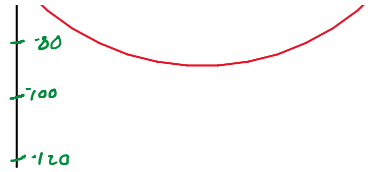
$C = \left(\frac{\sigma_x + \sigma_y}{2}, 0\right)$

$C = \left(\frac{0 + (99.47)}{2}, 0\right)$

$C = (49.73, 0)$

$R = \sqrt{(0 + 49.73)^2 + (57.25)^2} = 75.85$ MPa





g. Determine the motor power (W) to move the load, F, at a rate of 20mm/s.

Hint: based on the required linear translation of 20 mm/s you will need to find the required angular velocity in rad/s

$F = 5000$ N.

$v = .02$ m/s

$p = .004$ m.

$\frac{.02}{\pi(.008)} = .795$ rev/s

$.795(2\pi) = 5$ revs

$\omega = 2\pi n$

$P = T\omega$

$P = (5.756)(2\pi(5))$

$\boxed{P = 180.84 \text{ W}}$