Name of Student: Solution
(Last Name First Name)
Class Time (circle one): 7:30 11:30 2:30

ME 452: Machine Design II
Fall Semester 2014

Class Test 1c. Friday, October 10, 2014.
OPEN BOOK. CLOSED NOTES.
For Full credit show all of your work, including complete free-body diagrams.

The rotating, machined, steel shaft shown below is supported by bearings at both shoulders. The right bearing supports only radial load, and the left bearing can support axial load. Torque, T, applied to the left end of the shaft is transmitted, through the shaft to drive the grinding wheel on the right end. A stationary part (not shown) loads the grinding wheel with F_a and F_t as shown.

F_a = 400 lb (axial force)
F_t = 300 lb (tangential force)
S_y = 75,000 psi (shaft yield strength)
S_{ut} = 110,000 psi (shaft ultimate strength)
Reliability = 99%

For a critical point shown on the critical plane at the right shoulder (neglecting transverse shear stresses):

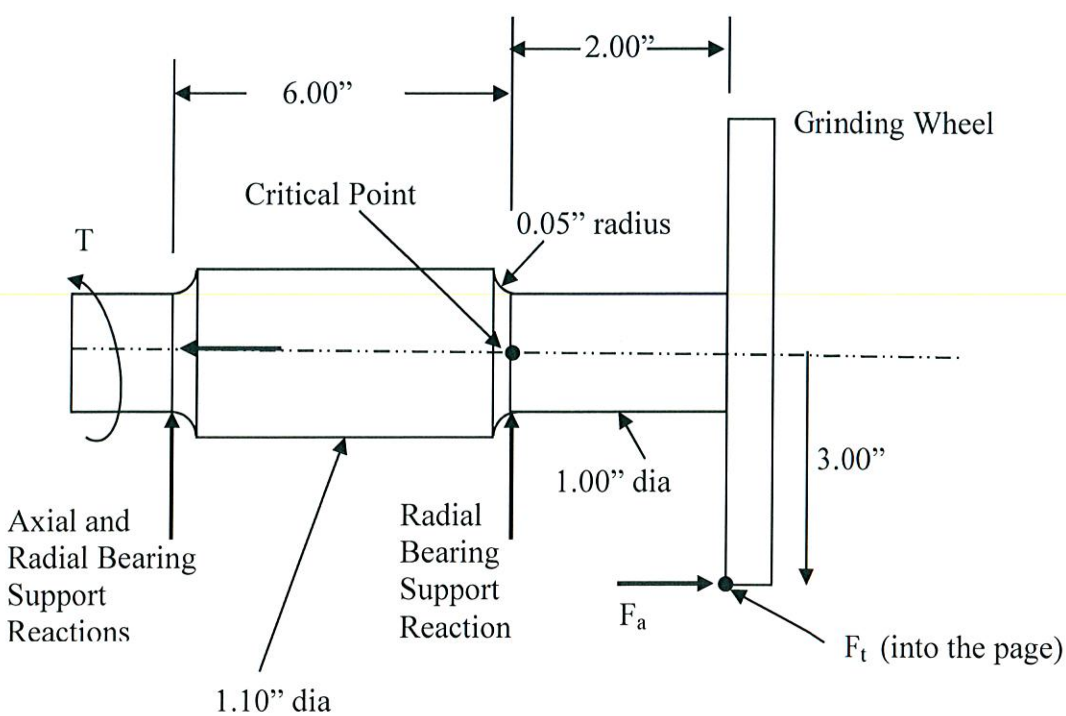
a. Calculate the nominal normal stress and plot it's variation with time.

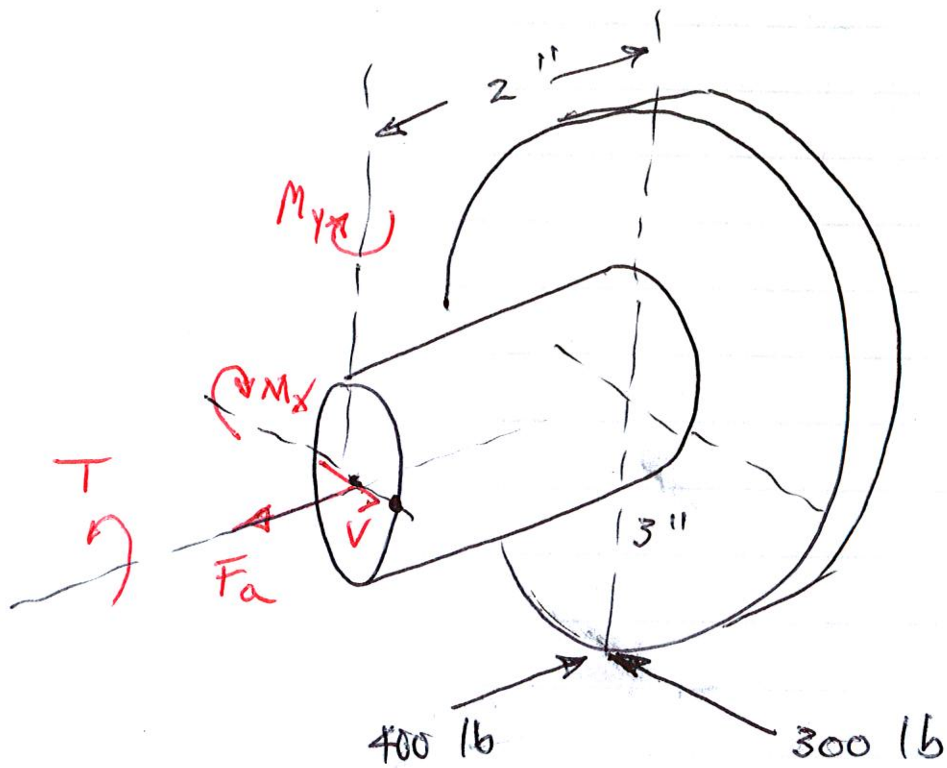
b. Calculate the nominal shear stress and plot it's variation with time.

c. Calculate the infinite life fatigue endurance limit.

d. Calculate the infinite life fatigue factor of safety using the Goodman failure criteria.

e. Calculate the yield factor of safety, including the stress concentration effects.





From the Free body diagram

$F_a = 400$ lb
$T = 900$ in lb
$M_x = 1200$ in lb
$M_y = 600$ in lb

$M_{max} = \sqrt{1200^2 + 600^2}$

$M_{max} = 1342$ in lb

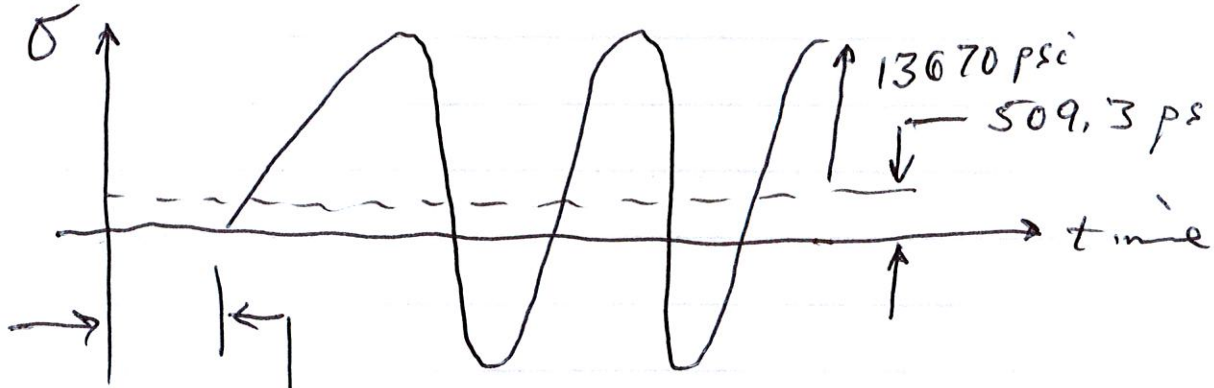
(Neglect) $V = 300$ lb

(a) Normal stress:

$$\sigma = \underbrace{\frac{M_{max}\, 32}{\pi d^3}}_{\text{alternate}} + \underbrace{\frac{4 F_a}{\pi d^2}}_{\text{midrange}}$$

$$\sigma_m = \frac{4F_a}{\pi d^2} = \frac{4\,(400)}{\pi\,(1)^2} = 509.3 \text{ psi}$$

$$\sigma_a = \frac{32 M_{max}}{\pi d^3} = \frac{32\,(1342)}{\pi\,(1)^3} = 13670 \text{ psi}$$

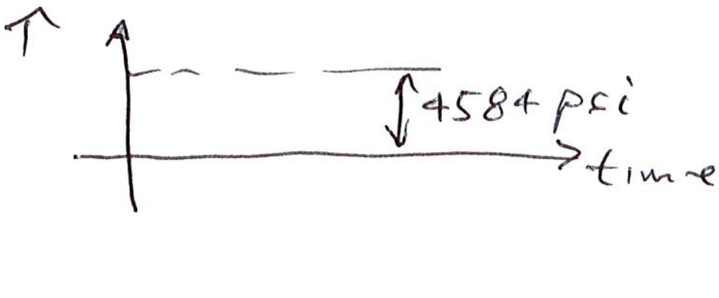


There is a phase because M_{max} is about some other axis.

(Assume This is negligible)

(b) $$\tau_m = \frac{Tr}{J} = \frac{16\,T}{\pi d^3} = \frac{16\,(900)}{\pi\,(1)^3} = 4584 \text{ psi}$$

$\tau_a = 0$ (steady torque)



(c) endurance limit

~~size:~~ Surface $a\, S_{ut}^{\,b}$ machined

$$k_a = 2.7\,(110)^{-.265} = .7770$$

$$k_b = \left(\frac{d}{.3}\right)^{-.107} = .8791$$

(No d_e needed)

$$k_c = 1$$

$$k_d = 1$$

$$k_e = .814$$

$$S_e = \frac{110}{2}\,(.777)(.8791)(.814)$$

$$= 30.58 \text{ kpsi}$$

(d) Stress Concentrations

$$\left.\begin{array}{l} D/d = 1.1 \\ r/d = .05 \end{array}\right\} \qquad \begin{array}{ll} K_t = 1.9 & \text{bending} \\ \quad\; 1.3 & \text{Torsion} \\ \quad\; 1.9 & \text{axial} \end{array}$$

from page 1028

$\sqrt{a}$ normal $= .0544$
$\sqrt{a}$ shear $= .0417$

$$\Rightarrow \text{bending} \quad K_f = 1 + \frac{1.9 - 1}{1 + \frac{.0544}{\sqrt{.05}}} = 1.724$$

$$\text{axial} \quad K_f = \text{same} = 1.724$$

$$\text{Torsion} \quad K_f = 1 + \frac{1.3 - 1}{1 + \frac{.0417}{\sqrt{.05}}} = 1.253$$

so

$$\sigma_a' = \sqrt{[(1.724)(13670) + 0]^2 + 3[0]^2}$$

$$= 23567 \text{ psi}$$

$$\sigma_m' = \sqrt{[0 + 1.724(509)]^2 + 3(1.253 * 4584)^2}$$

$$= 9987 \text{ psi} \quad (9948 \text{ Neglecting } F/A)$$

$$\Rightarrow n_f = \frac{1}{\frac{\sigma_m'}{S_{ut}} + \frac{\sigma_a'}{S_e}} = \frac{1}{\frac{9987}{110000} + \frac{23567}{30580}} = 1.161$$

(e)

yield

$$\sigma'_{max} \simeq \sigma_m' + \sigma_a'$$

$$= 9987 + 23567 \quad \text{(conservative)}$$

$$= 33554$$

includes stress conc.

$$n_y = \frac{S_y}{\sigma'_{max}} = \frac{75000}{33554}$$

$$\boxed{n_y = 2.235}$$