SOLUTION

University of Concordia
Department of Mechanical and Industrial Engineering
MECH 344/X-Machine Element Design
Quiz #1- Thursday Oct. 1, 2009

Instructor: Dr. Sedaghati
This examination paper has 5 pages.
TIME ALLOWED: 60 minutes

Special notes and instructions

1. OPEN BOOK EXAM (ONLY TEXT BOOK)
2. ENCS standard non-programmable calculator is allowed.
3. Write directly on this exam and bank pages provided. If necessary, write on the back of the facing page.
4. Write your Concordia ID on the space provided on the top of each page.
5. Show work in sufficient detail.
6. DO NOT UNSTAPLE PAGES.

I have read the above instructions

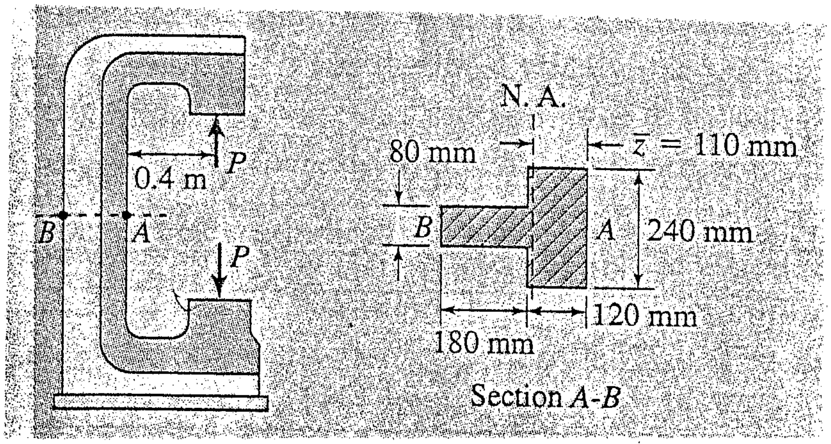
Signature: ______________________

Name: ______________________

Student ID: ______________________

Problem 1:

Figure below depicts a punch press frame made of gray cast iron with $S_{ut} = 170$ Mpa and $S_{uc} = 650$ Mpa. Assuming a safety factor of 2.5 and using Modified Mohr theory determine the maximum allowable load P.



Cross-sectional area of the section $A = 180 \times 80 + 120 \times 240$

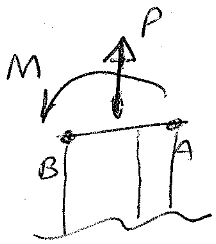
$\Rightarrow A = 43200\ mm^2 = 0.0432\ m^2$

Second moment of Area $I = \frac{1}{12} 80 \times 180^3 + (80 \times 180)(100)^2$

$+ \frac{1}{12} 240 \times 120^3 + (120 \times 240)(150)^2 = 289.44 \times 10^6\ mm^4$

$= 289.44 \times 10^{-6}$

The internal force resultants in section A-B are equivalent to a centric force P and a bending moment $M = 0.51P$



$110^{mm} = 0.11^{m}$

$\sigma_A = \frac{P}{A} + \frac{MC_A}{I} = 23.148P + 193.823P = 216.971P$ tensile

$190^{mm} = 0.19^{m}$

$\sigma_B = \frac{P}{A} + \frac{MC_B}{I} = 23.148P - 334.784P = -311.636P$ compressive

principal stresses at A $\sigma_1 = \sigma_A$, $\sigma_2 = \sigma_3 = 0$

" " " B $\sigma_1 = \sigma_B$, $\sigma_2 = \sigma_3 = 0$

$\longrightarrow$ next

Now Based on Modified Mohr theory

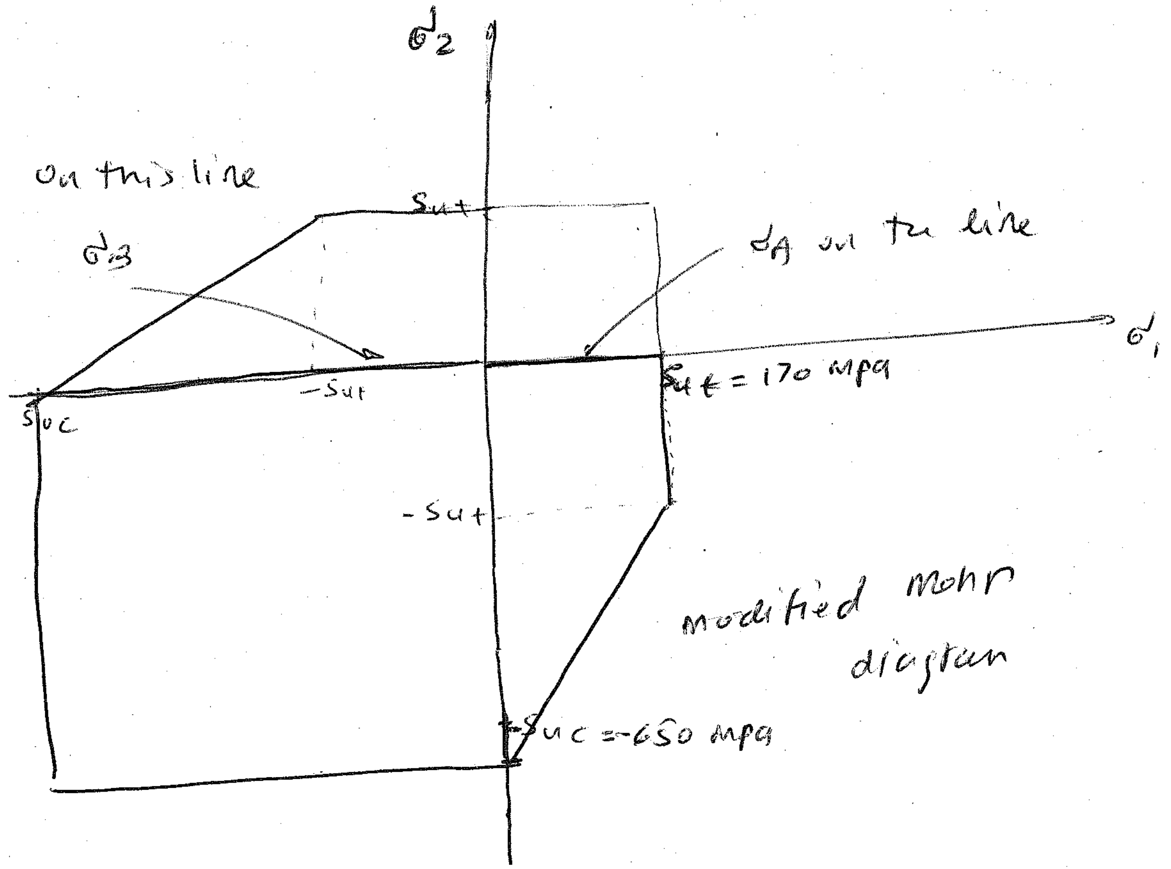
$\Rightarrow$

for point A : $N = \dfrac{S_{ut}}{\sigma_1} \Rightarrow 2.5 = \dfrac{170 \times 10^6}{216.971\, P} \Rightarrow$ or $P = 313.4$ KN

for point B: $N = \dfrac{|S_{uc}|}{|\sigma_3|} \Rightarrow 2.5 = \dfrac{650 \times 10^6}{311.636\, P} \Rightarrow$ or $P = 829$ KN

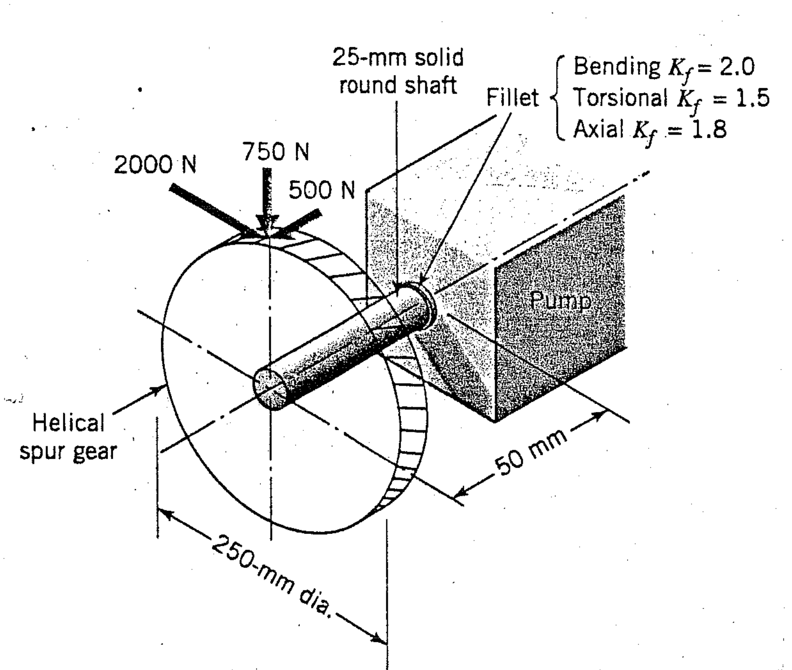
The maximum allowable load P is the smaller of the two loads calculated from the above relations

$\Rightarrow$ $\underline{P = 313.4 \text{ KN}}$ Maximum load that the member can carry



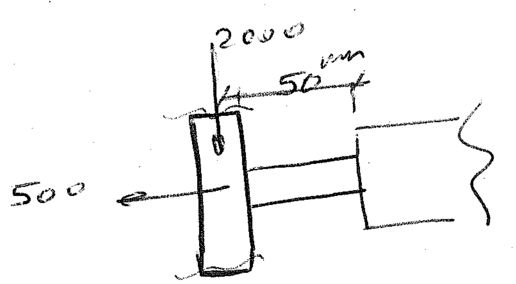
Problem 2:

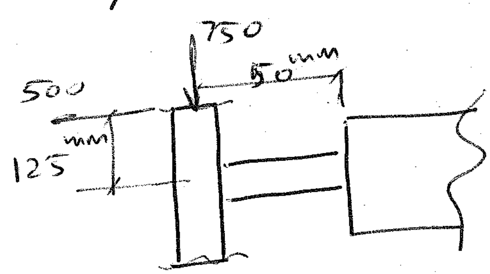
Figure below shows a portion of a pump that is gear-driven at uniform load and speed. The shaft is supported by bearings mounted in the pump housing. The shaft is made of AISI 1095 Carbon Steel quench & temper @600 °F. The tangential, axial, and radial components of force applied to the gear are shown. The surface of the shaft fillet has been perfectly polished, which is estimated to be equivalent to laboratory mirror-polished surface. Fatigue stress concentration factors (K_f) for the fillet have been determined and are shown on the drawing. Assume mean stress concentration factor K_{fm} is equal to K_f. Estimate the safety factor with respect to infinite fatigue failure at the fillet. Draw modified Good-man Diagram and show load line (use case 3). Assume room temperature and 50% reliability.



From Table C-9, P. 948 ; $S_{ut} = 1262$ MPa

$S_y = 814$ MPa





Vertical View

Horizontal View

$M_V = 2000 \times 50 = 100{,}000$ N.mm

$M_H = 500 \times 125 + 750 \times 50$
$= 100000$ N.mm

resultant $M = \sqrt{M_V^2 + M_H^2} \cong 141000$ N.mm

→ next

2/ Alternating stress

$$\sigma_a = K_f \frac{MC}{I} = K_f \frac{M d/2}{\pi d^4/64} = K_f \frac{32M}{\pi d^3} = 2 \times \frac{32 \times 141000}{\pi \times 25^3}$$

$$\Rightarrow \sigma_a = 183.8 \text{ Mpa}$$

$\sigma'_a = 183.8$ Mpa Effective Von Mises alternating stress

3/ Mean stress

$$\tau_m = K_{fm} \frac{TC}{J} = K_{fm} \frac{T d/2}{\pi d^4/32} = K_{fm} \frac{16T}{\pi d^3}$$

$$\Rightarrow \tau_m = \frac{1.5 \times 16 \times \overbrace{2000 \times 125}^{T}}{\pi \times 25^3} = 122.2 \text{ Mpa}$$

$$\sigma_m = K_{fm} \frac{P}{A} = K_{fm} \frac{P}{\pi d^2/4} = 1.8 \frac{500 \times 4}{\pi \times 25^2} = 1.83 \text{ Mpa}$$

$$\sigma'_m = \sqrt{\sigma_m^2 + 3\tau_m^2} = \sqrt{1.83^2 + 3 \times 122.2^2} = 211.7 \text{ Mpa}$$

4/ Endurance limit For steel, $S_e' \simeq 0.5\, S_{ut}$ for $S_{ut} < 1400$ Mpa

$$\Rightarrow S_e' = 0.5 \times 1262 = 631 \text{ Mpa}$$

$C_{load} = 1$, $C_{Temp} = 1$, $C_{reliab} = 1$, $C_{surf} = 1$

$C_{size} = 1.187\, d^{-0.097}$ for $8^{mm} \leq d \leq 250^{mm}$

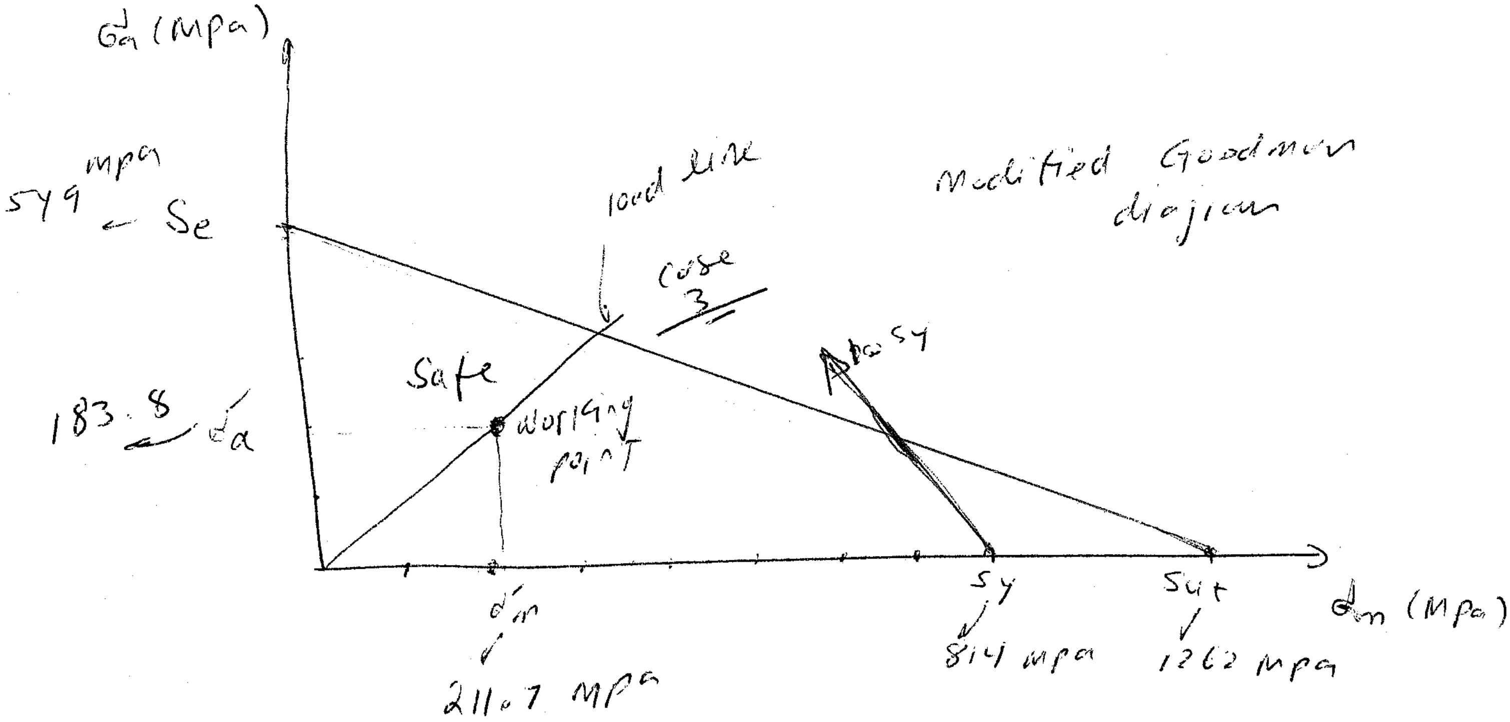
$$\Rightarrow C_{size} = 1.189\,(25)^{-0.097} = 0.87$$

$\Rightarrow$ $S_e = C_{load}\, C_{size}\, C_{surf}\, C_{temp}\, C_{reliab}\, S_e'$

-END-

Corrected endurance limit $= 1 \times 0.87 \times 1 \times 1 \times 1 \times 631 \simeq 549$ Mpa

$\longrightarrow$ back



safety factor $N_f = \dfrac{S_e \, S_{ut}}{\sigma'_a \, S_{ut} + \sigma'_m \, S_e}$

$$= \frac{549 \times 1262}{183.8 \times 1262 + 211.7 \times 549} \simeq \underline{\underline{2}}$$