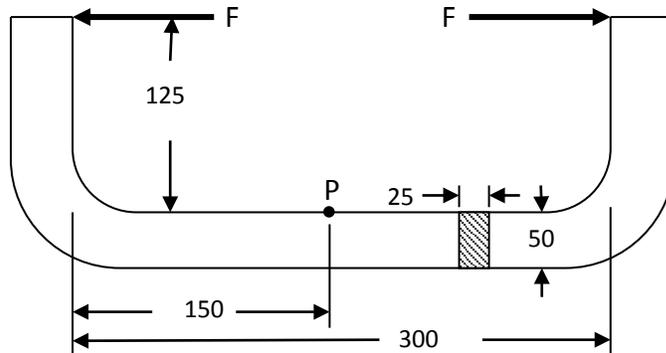


University of North Carolina at Charlotte
Department of Mechanical Engineering and Engineering Science
Sample Qualifying Examination

Machine Design

1. Reference Text: Fundamentals of Machine Component Design – 5th Edition, R.C. Juvinall and K.W. Marshek, Wiley, 2011.
2. Examination is open book.
3. Time: 3 hours.
4. Show all work in a neat and organized manner.

1. A flat steel bar with cross-sectional dimensions of 25mm X 50mm is bent into the shape shown below. The load F varies from 5000N to 20000N. The material has an ultimate tensile strength of 800 MPa, and a yield strength of 625 MPa.



- a. (5 pts) Find the endurance limit for the bar material assuming a machined finish, operating temperature below 125F, and 99% reliability.

$$S_n = \text{_____} \text{ MPa}$$

- b. (5 pts) Find the mean and alternating component of stress at point P.

$$\sigma_m = \text{_____} \text{ MPa}$$

$$\sigma_a = \text{_____} \text{ MPa}$$

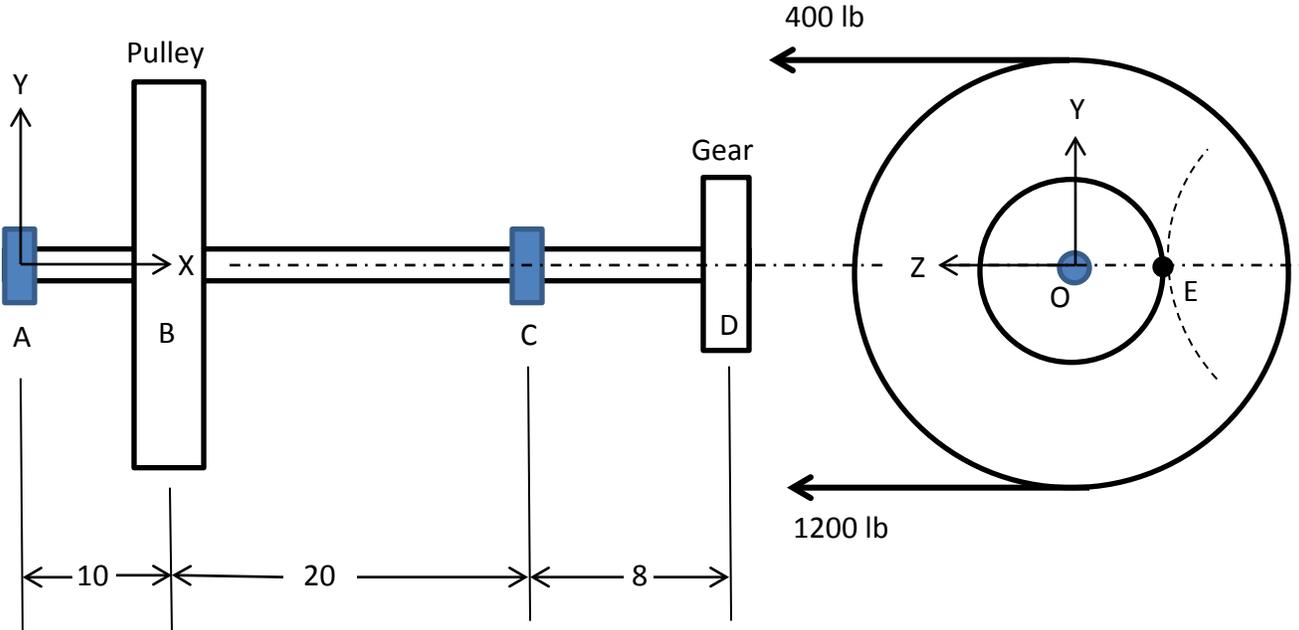
c. (5 pts) Find the factor of safety at point P for infinite life.

F.S. = _____

d. (5 pts) Find the factor of safety at point P for static loading.

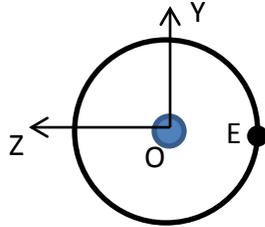
F.S. = _____

Problems 2 through 4 refer to the diagram below. A 24 inch diameter pulley is driven by a horizontal belt. The torque is transmitted through a 1.5 inch diameter solid steel shaft supported in bearings at A and C, to a 10 inch diameter pinion gear that mates with a 20 inch driven gear at point E. The belt forces are shown in the end view on the right. The shaft rotates at 500 rpm.



2. Gears

- a. (5 pts) Compute the gear tooth forces at the contact point E, and show them on the diagram below. Assume the gears have a 20 degree pressure angle.



- b. (10 pts) Assume the gears are made of steel with Brinell Hardness = 400, and have a Diametral Pitch, $P = 4$. Find the required face width for infinite life in bending with a factor of safety of 1.5. Assume the Velocity factor, $K_v = (1200 + V)/1200$, where V is in fpm. Assume $K_o = 1.5$, and $K_m = 2.0$; machined fillets in the gear teeth, 99% reliability, and temperature $< 160F$.

Face Width = _____ in.

c. (10 pts) Find the face width required for a life of 10^8 cycles with 99.9% reliability.

Face Width = _____ in.

3. **Shaft**

- a. (5 pts) Solve for the bearing support reactions in the vertical (XY) plane and in the horizontal (XZ) plane.

$$R_{AY} = \underline{\hspace{10em}} \text{ lbs.}$$

$$R_{AZ} = \underline{\hspace{10em}} \text{ lbs.}$$

$$R_{CY} = \underline{\hspace{10em}} \text{ lbs.}$$

$$R_{CZ} = \underline{\hspace{10em}} \text{ lbs.}$$

- b. (5 pts) Draw the bending moment diagrams for the shaft in the vertical (XY) and horizontal (XZ) planes, and show values for the bending moment at important locations.

- c. (5 pts) Identify the critical shaft section and compute the bending and torsional stresses at this section.

Critical Section _____

Maximum bending stress = σ = _____ psi

Maximum torsional stress = τ = _____ psi

- d. (5 pts) Draw Mohr's circle for stresses at the critical point and find the principal stresses and maximum shear stress.

Maximum principal stress = _____ psi

Minimum principal stress = _____ psi

Maximum shear stress = _____ psi

- e. (5 pts) Find the factor of safety against static failure using the Von Mises failure theory, assuming the shaft is made from 4340 HR steel.

Factor of Safety = _____

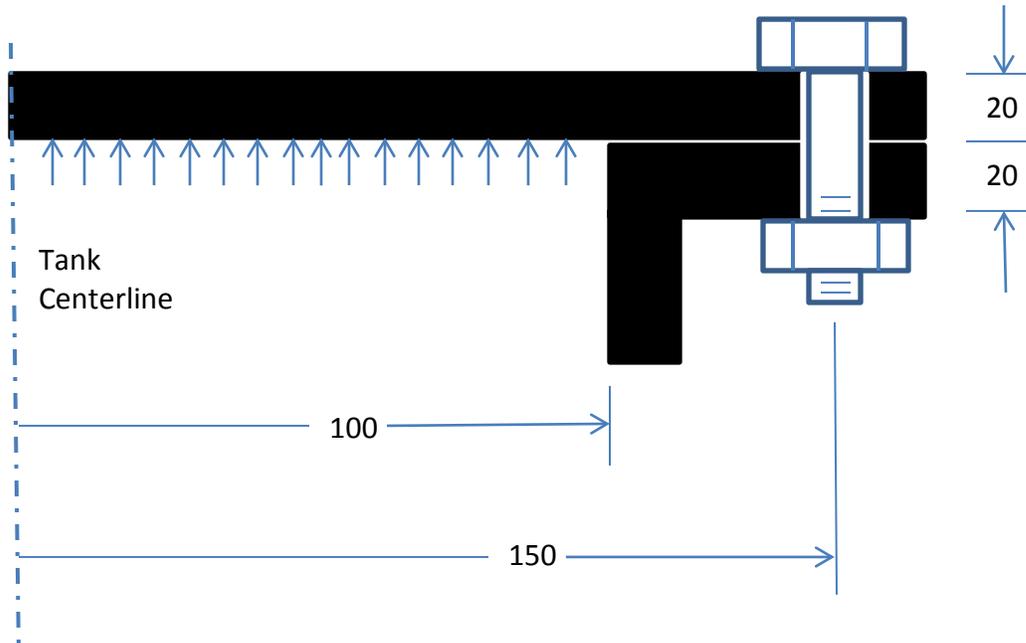
4. **Bearings** (20 pts)

The shaft is supported in identical ball bearings at points A and C. The ball bearings have a basic dynamic load rating of $C = 1450$ lbs, for a life of 90 million revolutions with 90% reliability. Find the expected life of each bearing with 95% reliability and assuming the shock application factor is $K_a = 1.2$.

Bearing A life = _____ revolutions

Bearing C life = _____ revolutions

5. An aluminum cylinder with ID = 200 mm has an aluminum cover plate bolted to it with ten M12, SAE class 8.8 steel bolts with rolled threads. Assume that the effective flange area compressed by each bolt is 4.5 times the cross sectional area of the shank of the bolt.



- a. (5 pts) The bolts are initially tightened to 80% of their proof strength. Find the initial tension in each bolt.

$F_{init} =$ _____ N

- b. (5 pts) What is the tensile force in each bolt when the cylinder is pressurized to 5 MPa?
Assume that the pressure load on the cover is carried equally by all of the bolts.

$$F_{\text{bolt}} = \underline{\hspace{10cm}} \text{ N}$$

- c. (5 pts) What is the maximum pressure the cylinder can hold before the force between the cover and cylinder falls to zero.

$$P_{\text{max}} = \underline{\hspace{10cm}} \text{ kPa}$$

d. (5 pts) What pressure in the cylinder will cause the bolts to reach their yield stress?

$P_{\text{yield}} =$ _____ kPa

6. A helical compression spring is made from ASTM A228 music wire. The free length of the spring is 1.75 in. The OD of the spring is 0.561 in., and the wire diameter is 0.055 in. The ends are squared and ground, and the *total* number of coils is 10. The normal operating load varies between 10 and 14 lbs. The expected number of loading cycles is 100,000.
- (10 pts) Find the factor of safety against fatigue failure.

Factor of safety = _____

- (10 pts) Find the maximum stress at the solid length.

$\tau_{\text{solid}} =$ _____ psi