ME 35400 – Machine Design I

Spring 2021: Exam 1

Tuesday, February 23, 2021

Name: ______________________ **Email:** ______________________

Instructions:

- This is an open book, closed notes exam.
- The use of any online sources, such as Chegg.com is not allowed. Failure to adhere to this will result in a score of 0 on this exam.
- Once completed, please upload a scanned PDF file on Gradescope.

Problem 1 (25 points):

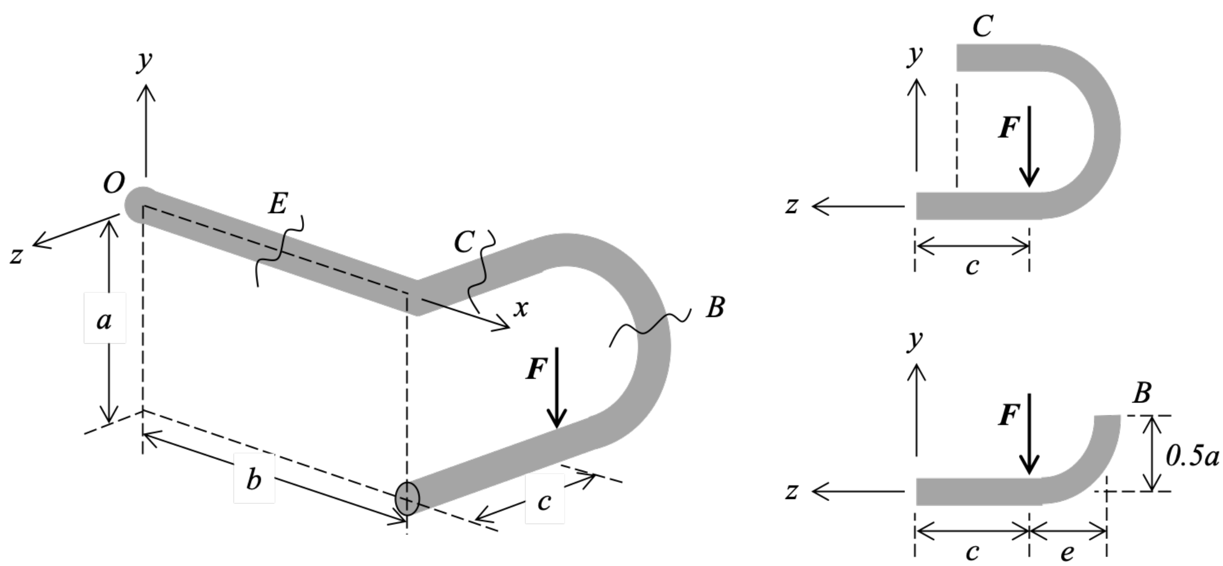
Given:. Drop handlebars have steered road bikes since the late 1800s.

A schematic of one half of a set of drop handlebars is shown below.

The handlebars are made of a hollow tube, with outer diameter $D = 1$ inch, inner diameter $d = 0.81$ inch, cross-sectional area $A = 0.27$ in^2, $I = 0.0280$ in^4, and $J = 0.0560$ in^4.

The handlebars are clamped at O.

Force $\vec{F} = -50\vec{j}$ lbf acts at the location shown. The handlebar dimensions are $a = 7$ inches, $b = 10$ inches, $c = 6$ inches, and $e = 3$ inches.



(i) For a cut through the handlebars at location B, the internal loads are (select all that apply):

- ◯ Axial compression
- ◯ Axial tension
- ◯ Torsion
- ◯ Bending
- ◯ Transverse shear

(ii) For a cut through the handlebars at location C, the internal loads are (select all that apply):

- ◯ Axial compression
- ◯ Axial tension
- ◯ Torsion
- ◯ Bending
- ◯ Transverse shear

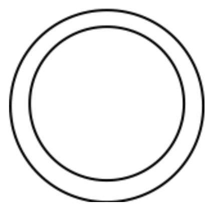
(iii) For a cut through the handlebars at location E, the internal loads are (select all that apply):

- ◯ Axial compression
- ◯ Axial tension
- ◯ Torsion
- ◯ Bending
- ◯ Transverse shear

(iv) Identify the critical cross-section of handlebars. Justify your choice.

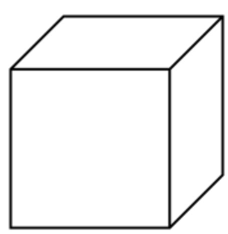
(v) Identify the critical element on the critical cross-section.

- Clearly show the location of the critical element on the sketch below.
- Clearly label the x-, y-, and/or z-axes.
- You may use the attached Stress Analysis Worksheet to aid your analysis.

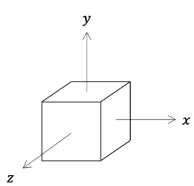
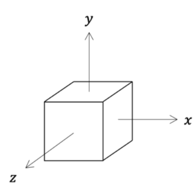
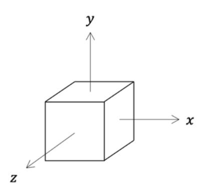
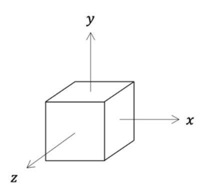
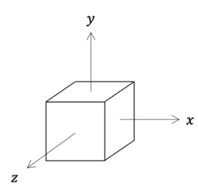


(vi) Draw the stress state for the critical element identified.

- Include the magnitude of each stress component.
- Clearly label the x-, y-, and z-axes.

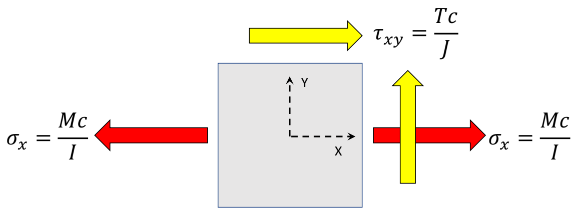


- Draw the machine component's critical cross-section.
- Identify and label the potential locations for the critical element(s) (e.g., top, bottom, right, left, and center)

Potential location of critical element						
Internal load	Axial					
	Torsion					
	Transverse shear					
	Bending					
Stress element						

Problem 2 (30 points):

Given:. A cantilevered solid rod with a circular cross-section is loaded with a constant force F and torque T at its free end. This results in a moment M = 75 N·m and a torque T = 45 N · m at the critical stress element at the wall (the critical cross-section) with the state of stress as shown below.



Part A. For a rod made out of AISI 1010 hot-rolled steel with S_{UT} = 40 MPa and S_y = 180 MPa, determine the minimum diameter d of the rod (rounded to the nearest 0.1 mm) to achieve a minimum factor of safety of 2.5 using:

(i) Maximum Shear Stress (MSS) theory
(ii) If the Distortion Energy (DE) theory was used to find the diameter, would you expect the diameter to be larger or smaller than the value found using the MSS theory and why?

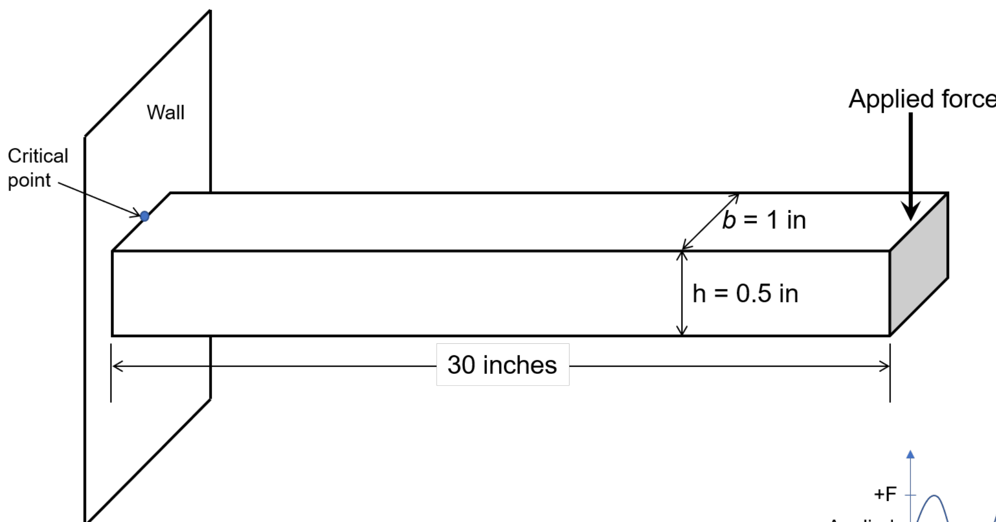
Part B. For the rod made out of ASTM 30 cast iron with S_{UT} = 214 MPa and S_{UC} = 752 MPa and a diameter d = 35 mm, determine the following:

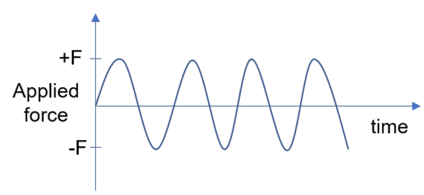
(i) Numerical values of the stresses σ_x and τ_{xy}.
(ii) The factor of safety using the brittle Coulomb-Mohr (BCM) theory
(iii) If the modified-Mohr (MM) theory was used to find the factor of safety (FOS), would you expect the FOS to be larger or smaller than the value found using the BCM theory and why?

Problem 3 (30 points):

A solid rod with a rectangular cross-section ($h = 0.5$ inch, $b = 1.0$ inch) is cantilevered at one end. The rod is 30 inches long, and supports a completely reversed transverse load at the other end of $\pm F$ lbf. The material is AISI 1045 hot-rolled steel. The rod operates at room temperature, and has a reliability of 99.99%. Neglecting any stress concentration, calculate the following for the critical point on the critical section at the wall:

(i) the uncorrected endurance strength, S'_e.
(ii) the fully corrected endurance strength of the rod, S_e.
(iii) the fatigue strength of the rod for 10^3 cycles.
(iv) the fatigue strength of the rod for 50,000 cycles, S_f.
(v) the life of the rod if the amplitude of the force is $F = 30$ lbf.
(vi) the maximum amplitude of the force F that would result in infinite life of the rod.

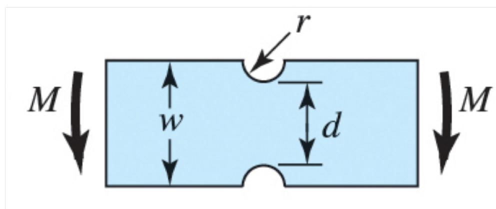




Problem 4 (15 points):

Given: A notched rectangular bar is made of AISI 1035 CD steel. The bar has dimensions $w = 1.5$ inches and $d = 1$ inch. The bar's thickness (the dimension into the page) is 0.5 inch.

When loaded in tension or simple compression, the bar's stress concentration factor is $K_t = 2.6$.



Determine the following for the notched rectangular bar loaded in bending.

(i) The notch radius, r.
(ii) The fatigue stress concentration factor K_f at the notch.
(iii) The stress at the notch if $M = 50$ in-lbf.