

AME 101 Fall 2017

Lecture homework #3

Assigned: 10/6/2017

Due: 10/13/2017, 4:30 pm, in the drop box in OHE 430N (back room of the OHE 430 suite of offices, where the Xerox machine is located) (Note this is a different box than my personal mailbox in the same room).

Problem #1 (20 points)

The “Fat Man” atomic bomb dropped on Nagasaki in 1945 used 14 lbm of plutonium (Pu) that was in a “subcritical” state (meaning, it would not explode) at its density at ambient pressure but would go “critical” under the immense pressure (thus increased density) created by squeezing it very rapidly with conventional high explosives. The density (ρ) of Pu at ambient pressure is 16.9 g/cm^3 , Poisson’s ratio (ν) is 0.21 and the modulus of elasticity (E) is $96.5 \times 10^9 \text{ Pa}$.

- What was the volume (= mass/density) of the Pu at ambient pressure?
- If the Pu was in the shape of a cylinder with equal diameter (d) and length (L), what was the diameter (in cm) at ambient conditions?
- If the Pu needs to be compressed to 24.4 g/cm^3 to explode, what strain ($\epsilon = \Delta L/L$) is needed to obtain this density? (Note that as you compress it (reduce L), the diameter d increases so you need to consider Poisson’s ratio to determine net change in volume and thus change in L required)
- What normal stress (σ) (in lbf/in^2) is required to produce this amount of strain?
- What force (in lbf) is required to produce this normal stress?

Problem #2 (20 points)

A hollow cylinder 10 feet long has an outside diameter of 2 inches and a 1 mm thick wall. The yield stress of the wall material is $5 \times 10^3 \text{ lbf/in}^2$ in tension, $1.5 \times 10^3 \text{ lbf/in}^2$ in compression, and $1 \times 10^3 \text{ lbf/in}^2$ in shear.

- At what pressure difference would this cylinder fail (due to the stress exceeding the yield stress of the material) if the high pressure were inside the cylinder? Would it fail in tension, compression or shear?
- At what pressure difference would this cylinder yield if the high pressure were outside the cylinder? Would it fail in tension, compression or shear?
- If the cylinder had welded end caps made of the same material and having same wall thickness as the cylinder, would the end caps fail at a lower or higher pressure than the value you calculated for part (a)?

Problem #3 (20 points)

- Suppose instead of being a pressure vessel, the pipe of problem 1 is used as a beam and a uniform load (w) of 10.3 lbf/ft is applied. What is the maximum normal stress (in units of lbf/in^2) in the cylinder wall material with this beam loading?
- If the maximum deflection at the center of this beam is 0.1 inch, what is the elastic modulus (E) of the cylinder wall material?

Problem #4 (20 points)

A 6061-T6 aluminum pipe (see Table 2 of the lecture notes for properties) has a diameter of 5 cm, a wall thickness of 1/8 inch and a length of 10 feet. Assume that the aluminum has the same yield strength in tension, compression and shear.

- (a) What is the maximum pressure this pipe could hold without yielding?
- (b) If instead this pipe is used as a beam, what is the maximum distributed load (w , units lbf/ft) that could be applied without yielding?
- (c) If **both** of the loads from parts (a) and (b) were applied simultaneously, what would the maximum shear stress in the pipe be? (Assume that somehow the pipe didn't yield).
- (d) If instead of applying the loads in parts (a) and (b), the pipe were oriented vertically and used as a column, what is the maximum load (in lbf) that the pipe could support without buckling? Assume both ends of the column are tightly clamped.

Problem #5 (20 points)

- (a) Do an experiment to estimate the stress at failure of a piece of spaghetti. (You'll need to do this anyway for the 2nd group project). Get a strand of spaghetti, measure its dimensions, suspend it between two tables, hang a uniform load from it, and add weight until it fails. From the formulas given in the lecture notes, calculate the maximum of the moment $M(x)$ in the beam, and determine the stress that it causes from using the moment of inertia calculated from the formula for a round cross-section. Try to load the "beam" as uniformly as possible to match the assumptions made in the analysis. Note that you don't have to use a full-length strand of spaghetti; if you want a larger weight at failure, use a shorter piece of spaghetti. You can estimate the weight on the spaghetti without a scale by using a paper cup filled with a measured volume of water (mass = density x volume) and hung on the spaghetti with a string.
- (b) Repeat part (a) for a point load in the middle of your strand of spaghetti. Do the two experiments give the same result for the stress at failure?