22.06 **ENGINEERING OF NUCLEAR SYSTEMS - Fall 2010**

Problem Set 10

Structural Mechanics

1) The (uniaxial) tensile stress data listed in Table 1 are for a cylindrical coupon of initial length and diameter, 50 mm and 7 mm, respectively. Calculate the following parameters:

- Young's Modulus, E (GPa)
- The Yield Stress, S_y (MPa)
- The Ultimate Stress S_u (MPa)

Table I

L (mm)	Force (kN)
50.000	0.00
50.012	2.00
50.025	4.00
50.038	6.00
50.057	8.00
50.131	9.99
50.501	11.90
52.113	13.45
55.467	13.89
69.751	12.43
129.415	7.44

2) Two sections of stainless steel cylindrical piping of different wall thickness are joined by welding. Before an internal pressure p_i (above atmospheric) is applied (assume no outside pressure above atmospheric), the geometry of the piping is as shown in Figure 1.1. The numerical values of geometry and pressure p_i are given in Table 1.1. You can assume the piping is capped at both ends to hold the internal pressure. Stainless steel properties are given in Table 1.2.

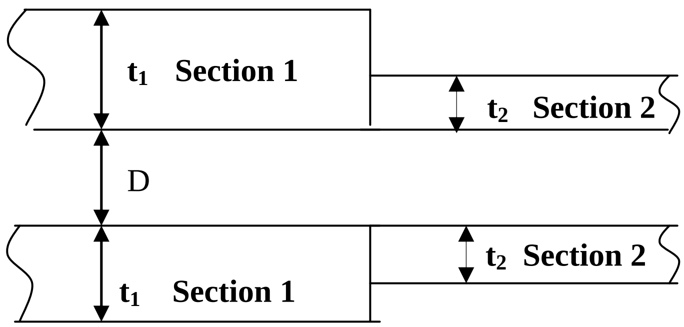

Fig 1.1 (not to scale)

Table 1.1
D, cm = 100
t_1, cm = 4
t_2, cm = 2
p_i, MPa = 7

<u>Stainless Steel</u>

Modulus of elasticity, E	2 x 10^5 MPa
Poisson's ratio, γ	0.3
Density, ρ	8,000 kg/m^3

Table 1.2

<u>Questions:</u>

a) Calculate the principal stresses in both sections of the piping (far away from the junction) when the internal pressure p_i is applied.

b) Sketch the geometry of the piping after internal pressure p_i is applied. Your sketch should clearly show the relative displacements of the two pipe sections and rotations of the material about the location they are joined. Further you should explain and justify the key features of your sketch in words.

3) A stainless steel spherical vessel of dimensions shown in Fig. 3 is subjected to an external pressure of 0.5 MPa and an internal pressure, p_i.

QUESTIONS

Assume failure is to be evaluated by the maximum elastic energy theory (i.e., Von Mises theory) with a yield stress of 690 MPa.

1) What is the maximum internal pressure that will not fail the vessel? Other stainless steel properties are given below.
2) What is the radial displacement corresponding to the maximum internal pressure?

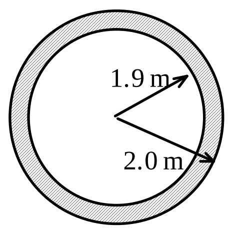

Figure 3. (not to scale)

Stainless Steel

Modulus of elasticity, E	200 GPa
Poisson's ratio, γ	0.3
Density, ρ	7,750 kg/m^3
Coefficient of linear expansion, α	1.6x10^{-5}/°C

4) Consider a PWR pressure vessel that operates at 15 MPa and 320°C. The vessel is made of carbon steel, and has a diameter of 4.5 m and a thickness of 200 mm. If due to a seismic event the vessel is also subjected temporarily to an external compressive axial force F_s, as shown in Figure 1, what is the maximum allowable value of F_s, so that the Tresca limit for the stresses is not violated? (S_y = 270 MPa for carbon steel at 320°C)

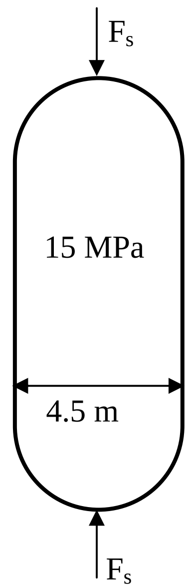

Fig. 1. (not to scale)

Assumptions

1) Use a thin-shell approach to calculate the principal stresses.
2) Neglect the external pressure.