STRUCTURAL MECHANICS PROBLEMS

Problem S.3 – Sizing the pressure vessel for a CO_2-cooled reactor

Japan Steel Works, the world's leading manufacturer of nuclear reactor pressure vessels, has established that components of weight up to 300 ton (300,000 kg) can be fabricated in its heavy workshop. You are to calculate the maximum allowable diameter of a cylindrical shell that is 4 m high and is made of carbon steel, to be used in a gas-reactor pressure vessel that will operate at 350°C and 20 MPa.

Assumptions:

- Use a thin-shell approximation to calculate the stresses.
- Assume that the external pressure is atmospheric.
- Use the ASME code primary general membrane stress requirements.
- The value of the maximum allowable stress intensity, S_m, for carbon steel at 350°C is 220 MPa.
- The density of carbon steel is 7,000 kg/m^3.

Problem S.4 – Molten-lead pressure vessel

Fast reactors have attracted renewed attention within the nuclear community because of their ability to consume the actinides from the LWR spent fuel. Consider the vessel of a liquid-lead-cooled fast reactor, which is made of stainless steel with the dimensions shown in Figure S.1. The top of the vessel is filled with a cover gas (nitrogen) whose operating temperature and pressure are 400°C and 0.5 MPa, respectively. The pressure outside the vessel is 0.1 MPa.

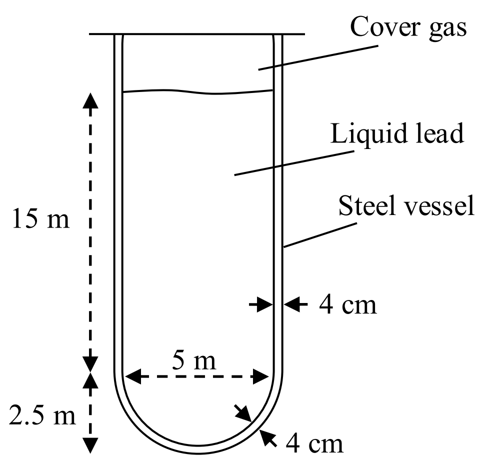

Figure S.1. Schematic and dimensions of the vessel.

Assuming that the stresses can be calculated using the local value of the pressure, identify the location of maximum primary general membrane stress intensity in the vessel and calculate the margin to the ASME limit (S_m) at that location. Use the thin shell approximation and consider the effect of gravity on pressure within the liquid lead.

Properties

Stainless steel: S_m=138 MPa at 400°C, Density 7500 kg/m^3, Young's modulus 170 GPa

Lead: Density 10500 kg/m^3, Viscosity 1.6×10^{-3} Pa·s, Boiling point 1750°C

Nitrogen: c_p=1039 J/kg·K, R*=297 J/kg·K, γ=1.4

J. Buongiorno, 12/6/14

Problem S.5 – Stresses in the shell of a centrifuge for uranium enrichment

Uranium enrichment can be accomplished in centrifuges consisting of a cylindrical shell made of Al-7075-T6 (an aluminum alloy), rotating at very high speed (50,000 rpm). A continuous feed of Uranium hexafluoride gas (UF_6) at sub-atmospheric pressure (P_i = 50 kPa) is fed to the centrifuge; the pressure outside the centrifuge is atmospheric. You are to calculate the hoop stress (σ_θ) in the shell of one such centrifuge. Recall that, in a rotating frame of reference, the centrifugal force (per unit volume of material) is equal to $\rho\,\omega^2 R$, where ρ = 2800 kg/m^3 is the density of Al-7075-T6, ω is the angular speed (rad/s) of the centrifuge, and R = 6 cm is the centrifuge radius. The shell thickness is t = 1 mm and the shell length is L = 65 cm.

How does the value of the hoop stress compare to the yield strength of Al-7075-T6 (S_y = 505 MPa)?