# STRUCTURAL MECHANICS PROBLEMS

**Problem S.1 - Sizing the silicon carbide layer in a TRISO fuel particle**

A TRISO fuel particle can be modeled as a small spherical pressure vessel of radius 280 μm and with the wall made of silicon carbide (SiC). The internal pressure is due to the build-up of fission gases, while the external pressure is a constant 8 MPa (i.e., the pressure of the reactor coolant). At the end of the irradiation cycle the fuel particle contains 0.1 μmol (=$10^{-7}$ moles) of fission gases and operates at 950°C.

Estimate the minimum required thickness of the SiC wall to prevent failure.

*Assumptions*

Use a thin-shell approximation and the Von Mises failure criterion for your analysis. Assume the fission gases occupy only 30% of the volume within the fuel particle. The fission gases can be treated as a perfect gas (R=8.31 J/mol-K).

*Properties of SiC at 950°C*

Yield strength: 200 MPa
Density: 3200 kg/$m^3$
Young's modulus: 400 GPa
Poisson's ratio: 0.28

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**Problem S.2 – PWR fuel pin with a thin gap and no fill gas**

A bright 22.312 student wants to reduce the gap thickness in the fuel pin of a PWR, in the hope to decrease the thermal resistance of the gap, and thus be able to operate the fuel at lower temperatures. He also wants to eliminate the helium fill gas, to cut manufacturing costs.
His new fuel pin design has the following *as-manufactured* dimensions:

- $UO_2$ pellet radius: 4.1 mm
- Gap thickness: 10 μm
- Zircaloy clad thickness: 0.4 mm

i) During normal operation, the fuel pellet radius expands by 0.5% due to irradiation effects. As a result, the clad and pellet make contact. Assuming a coolant pressure of 15.5 MPa, calculate the value of the force per unit area exerted by the fuel pellet on the clad, $P_i$, in this situation. (*Hint*: assume that the fuel pellet is perfectly rigid).

ii) For the situation described in 'i', calculate the principal stresses in the clad and judge their acceptability using the Tresca criterion.

iii) What are the merits and shortcomings of the student's idea?

*Assumptions*

Treat the clad as a thin shell.

*Properties of Zircaloy at the temperatures of interest*

Yield strength: 200 MPa
Density: 6600 kg/m$^3$
Young's modulus: 80 GPa
Poisson's ratio: 0.35

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