HW 4 NucE 497

**Problem 1**

Discuss the meaning of UO2 stoichiometry and why it is important for fuel performance. In your discussion, be sure to define what stoichiometry change means chemically and define the O/M ratio.

**Problem 2**

In this problem you will model the grain growth in a UO2 fuel pellet with a radius of 4.5 mm, a thermal conductivity of 0.03 W/(cmK), and an initial average grain size of 10 microns. It is experiencing a linear heat rate of 250 W/cm and has a surface temperature of 800 K. Assume that the temperature profile of the pellet can be predicted using the steady state analytical equation.

1. Calculate the grain boundary mobility in the fuel pellet at the pellet center, half way through the radius, and on the outer edge.
2. Calculate the average grain size in the fuel pellet using the equation from slide 22 of lecture 20. Plot the average grain size with time for a year at the three locations used in part a).
3. When modeling fuel performance, do we need to consider grain growth near the edge of the fuel pellets? Explain your answer.

**Problem 3**

In this problem you will predict the change in the fission gas concentration in the gap of a fuel rodlet. It is directly applicable to the final project and you will use the same rodlet dimensions from the project, but assume that the fuel is one long perfect cylinder. The initial rodlet is filled with He gas to a pressure of 2 MPa at 273 K.

1. Compute the number of moles of He gas used to initially fill the fuel rod. Assume the He behavior is an ideal gas (note, this problem is very similar to problem 2, part a) from HW 3).
2. Derive an expression for the average temperature change across the radius of the fuel pellet using the steady state analytical expression. Remember that the average value can be determined using the expression:  
   \bar{f} = \frac{1}{b - a} \int\_a^b f(x) dx
3. Use the expression from part b to determine the average temperature within the fuel pellet using the conditions from the project once the rodlet reaches full power and only use the max power (ignore the axial power profile). Also, what is the average pellet temperature assuming a pellet surface temperature of 800 K?
4. Again using the conditions from the project once the rodlet reaches full power (for the max power) and assuming that the temperature in all the pellets is equal to the average temperature you calculated in part b), determine the concentration of fission gas in the gap and plenum. Plot this concentration vs time for two years.
5. Explain how you would implement this model for the project, using the approach you have selected.

**Problem 4**

In this problem you will compute the total volumetric change of the fuel in a fuel rodlet. It is directly applicable to the final project and you will use the same rodlet dimensions from the project.

1. Determine the total volumetric change in a fuel pellet through the time the rodlet is operating at the conditions set in the project but ignore the axial power profile; include thermal expansion, densification, and swelling. For the temperature, assume a pellet surface temperature of 800 K and use the expression for the average temperature change you derived in problem 3, part b). Plot the volume change vs time.
2. Use the analytical equations to plot the temperature profile through the fuel, gap, cladding, and coolant at the end of life of the fuel rodlet from the project (again, ignore the axial power profile). Use the iterative method discussed in module three to include the impact of all the volume changes of the pellet on the gap.
3. Explain how you would implement this model for the project using the approach you have selected.

**Problem 5**

In this problem you will investigate the impact of burnup on the fuel thermal conductivity and the fuel centerline temperature using the NFIR model. Use the conditions and fuel rodlet dimensions from the project.

1. Plot the thermal conductivity of UO2 with a temperature of 1200 K vs time throughout the lifetime of the fuel rodlet from the project.
2. Plot the fuel centerline temperature within the pellet vs time throughout the lifetime of the fuel rodlet. Calculate the temperature using the steady-state analytical equation for a pellet surface temperature of 800 K. Use the thermal conductivity calculated in part a).
3. Explain how you would implement the NFIR model for the project using the approach you have selected.