Homework #6

Web Problem #6

Nuclear Reactor Safety Analysis

1. For a PWR cylindrical solid fuel pellet (pellet diameter = 10 mm, density = 95% theoretical density) operating at a heat flux equal to 1.7 MW/m^2 and a surface temperature of 400˚C, calculated the maximum temperature in the pellet assuming thermal conductivity is independent of temperature.
2. For a PWR fuel pin with a pellet radius of 4.7 mm, clad inner radius of 4.89 mm, and the outer radius of 5.46 mm, calculate the maximum linear power that can be obtained from the pellet such that the peak temperature in the fuel does not exceed 2400˚C. Assume a bulk fluid temperature on the outside of the fuel pellet to be 307.5˚C and the coolant heat transfer coefficient to be 28.4 $kW/m^2\cdot$˚C. In the gap, consider only conduction heat transfer.

   Fuel conductivity = 3.011 W/(m·˚C)
   Clad conductivity = 18.69 W/(m·˚C)
   Gap conductivity = 0.277 W/(m·˚C)

3. **TEAM PROBLEM:** Consider your reactor design to date. You likely do not yet know the actual radius (though you did calculate the minimum in the last homework), since this depends on the neutronics. However, it is possible to develop a radial temperature distribution based on a radius of your core. This problem consists of two parts:

   1) Assume a radial configuration for your MSR. If it is a homogeneous core, create a temperature distribution (as a function of radius) for the fluid, any coatings, and the containment vessel. If it helps, you may assume a single radial temperature distribution at height of max heat production. Use the reactor power rating and minimum core radius you selected/calculated last time to indicate the q', and from there develop an equation to indicate the radial temperature distribution for each region of core.
   2) Guess a reasonable radius for your reactor (based now solely upon thermal properties, as compared to based upon k_{eff} from previous homework). Indicate what the inner and outer vessel temperatures (maximum) are. Adjust the size until these temperatures are acceptable for your given vessel wall material (assume a heat generation margin of 1.5). What is the new actual Q value of your reactor? Adjust your radius within a reasonable amount and determine whether the power you stated is possible without breaking thermal limits. Also note whether the core diameter is constrained to be below the radius indicated for k_{eff}. Please report each of the parameters you calculated for your reactor core. Also, list all assumptions, boundaries, and correlations assumed for this problem.