Exam 2: NE33: Nuclear Fuel Performance

1. Consider a fuel rod with a pellet radius of 4.5 mm that is experiencing a linear heat rate of 250 W/cm.
   1. What is the maximum stress experienced by the pellet, assuming that the fuel has k = 0.1 W/cm-K, E = 290 GPa, ν = 0.3, and α = 8.2e-6 1/K? (10 pts)
   2. Given =120 MPa, how far do cracks extend into the fuel? (4 pts)
2. Consider the stress state in a zircaloy-clad fuel rod pressurized to 50 MPa with an average radius of 5.4 mm and a cladding thickness of 1.2 mm.
   1. Calculate all three components of the stress using the thin-walled cylinder approximation. (4 pts)
   2. Calculate all three components of the stress at r=5.6 mm assuming a thick-walled cylinder. (6 pts)
   3. Calculate the maximum strain, with the stress components from (b) and with E=180 GPa and ν=0.28. (4 pts)
3. Calculate the change in the gap thickness due to thermal expansion. Only perform one adjustment to the gap thickness. Rf = 0.52 cm. tgap = 0.005 cm, TCO = 550 K, tclad = 0.08 cm, kfuel = 0.05 W/cm-K, kgap = 0.003 W/cm-K, kclad = 0.15 W/cm-K, LHR = 225 W/cm, αc = 4.5x10-6 1/K, αf = 15x10-6 1/K, Tref(fuel=clad) = 300 K. (16 pts)
4. A fuel pellet with an average grain size of 8 microns is irradiated with a volumetric neutron flux of 2.0e13 fissions/(cm3-s). Assume the diffusion coefficient is 2x10-15 cm2/s. How many gas atoms/cm3 are released from the fuel after 2 years of irradiation? Assume the yield = 0.3017. (12 pts)
5. Define strain hardening. What causes strain hardening? (8 pts)
6. Name three properties that vary as a function of stoichiometry in UO2. (6 pts)
7. What three things must all fuel performance codes be able to do? (6 pts)
8. List the three stages of fission gas release. (9 pts)
9. What performance effects result from the High Burnup Structure? (6 pts)
10. Provide an example of a 0-D defect. Provide an example of a 3-D defect. (4 pts)
11. What is the driving force for fuel densification? What is the driving force for grain growth (6 pts)
12. What is the valence state of U in UO2? What are the possible valence states of U? (4 pts)