Exam 2: NE533: Nuclear Fuel Performance

1. (12 pts) Consider a fuel rod with a pellet radius of 0.45 cm that is experiencing a linear heat rate of 250 W/cm.
   1. What is the maximum stress experienced by the pellet? kf = 0.1 W/cm-K, E = 290 GPa, ν = 0.25, and α = 12x10-6 1/K?
   2. Given =120 MPa, how far do cracks extend into the fuel?
2. (16 pts) Consider the stress state in a zircaloy-clad fuel rod pressurized to 25 MPa with an average radius of 0.52 cm and a cladding thickness of 0.08 cm.
   1. Calculate all three components of the stress using the thin-walled cylinder approximation.
   2. Calculate all three components of the stress at r=0.5 cm assuming a thick-walled cylinder.
   3. Use constitutive relationships to calculate the hoop strain with the stress components from (b) and with E=160 GPa and ν=0.3.
3. (14 pts) Calculate the change in the gap thickness due to thermal expansion. Do not perform iterations. Rf = 0.52 cm. tgap = 0.005 cm, TCO = 550 K, tclad = 0.08 cm, kfuel = 0.04 W/cm-K, kgap = 0.003 W/cm-K, kclad = 0.15 W/cm-K, LHR = 400 W/cm, αc = 12x10-6 1/K, αf = 8x10-6 1/K, Tref(fuel=clad) = 300 K.
4. (12 pts) Perform a forward Euler time stepping to approximate the function. Compute with a timestep of dt=0.25, expanding to tn=1.0. dy/dt = -5y; t0 = 0; y0 = 1
5. (10 pts) What is the max hoop stress in the cladding due to thermal expansion? DTc=250 K; ac=8x10-6; E=250 GPa; n=0.3; tc=0.1 cm; Ri=0.55cm. Where is the hoop stress equal to zero?
6. (6 pts) What are three ways that space is discretized for numerical solutions? Name a strength or weakness of one of these types.
7. (8 pts) Define strain hardening. What causes strain hardening?
8. (5 pts) What three things must all fuel performance codes be able to do? List two fuel performance codes currently being utilized.
9. (4 pts) Provide an example of a 0-D defect. Provide an example of a 3-D defect.
10. (8 pts) Describe the concept of microstructure-based fuel performance modeling and why it is beneficial.
11. (5 pts) What leads to the possibility of oxide fuel pulverization/fragmentation in the HBS? How are scientists addressing this topic?
12. (5 pts) What is meant by microstructure and how is it tailored?