75/100

NucE 497 Fuel Performance Exam 2 covering modules 4 – 6

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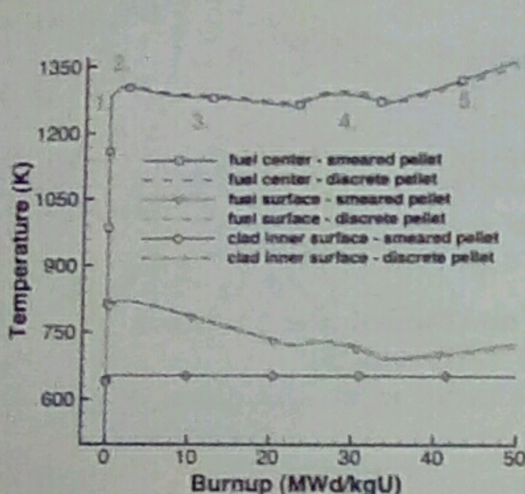
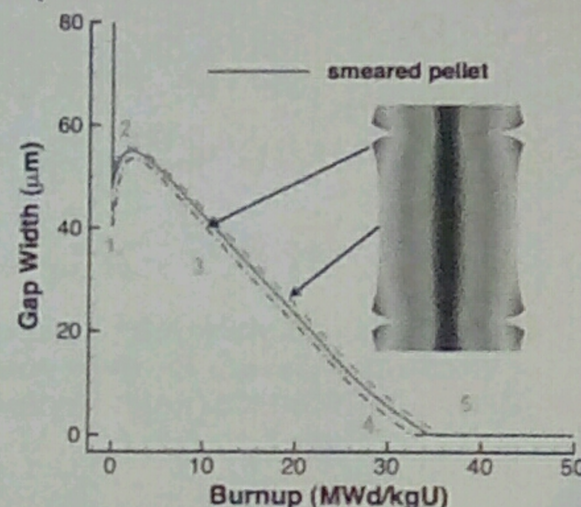
-7, 18/25

Question 1 (25 points):

The temperature and gap width of a fuel pellet, as predicted by a fuel performance code, is shown below. Using the plots as your guide, determine what is currently occurring within the cladding, gap, and pellet at each number. Note that the numbers are at the same burnups on the two plots.





For each number, describe what is occurring in the cladding, gap, and pellet. Also, describe what features in the plots indicated these behaviors.

1. As temperature of fuel rapidly increase, increase in temperature of gap and cladding occurs. The fuel expands and the gap decreases

2. Fuel densifies & gap width (compresses) pressure and temperature decrease
fission gases segregate to voids

3. Gap experiences continued decrease in width. Fuel expansion is observed. Gas release to plenum & gap decrease thermal conductivity so no significant change in temperature for cladding -1, Swelling

4. At high burnup, cladding & fuel experiences creep and corrosion. This begins to lead to pellet cladding interaction.
-2, fission gas release causes T increase before gap closure

5. After fuel is burned out, gap width reaches steady state. Temperature of the fuel + cladding doesn't significantly change.
-4, T in fuel steadily increases due to decrease in fuel k with burnup

Question 2 (30 points)

-12, 18/30

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 pellet is at a uniform temperature of 900 °C.

a) What is the fission gas diffusion coefficient at this temperature? (5 pts)

$D = D_1 + D_2 + D_3$ cm^2/s

$T = 900°C$

$D_{grain\,size} = 8 \cdot 10^{-6}$

$\dot{F} = 2 \cdot 10^{13}$ fission/cm³s

$k_B = 8.617 \cdot 10^{-5}$ eV/K

$D_1 = 7.6 \cdot 10^{-4}\, e^{\frac{-3.03\,eV}{(k_B)(900+273)}} = 6.858 \cdot 10^{-19}$

$D_2 = 1.41 \cdot 10^{-18}\, e^{\frac{-1.19\,eV}{(k_B)(900+273)}} \left(\sqrt{2 \cdot 10^{13}}\right) = 4.749 \cdot 10^{-17}$

$D_3 = 2 \cdot 10^{-30}(2 \cdot 10^{13}) = 4 \cdot 10^{-17}$

-2, Wrong D, D = D1 + D2 + D3 = 8.94e-17 cm2/s

$D = 6.858 \cdot 10^{-19}$ cm^2/s

b) How many gas atoms/cm³ are released from the fuel after 2 years of irradiation? Assume the chain yield y = 0.3017. (10 pts)

$N_{fission\,x} = y\dot{F}t$

$= (0.3017)(2(365)(24)(60)(60))(2 \cdot 10^{13})$

$= 3.8057 \cdot 10^{20}$ gas atoms/cm³

-6, I asked for gas RELEASED, not produced. You need to calculate f

c) After 2 years of irradiation, the pellet is removed from the reactor and from its cladding, venting all released gas. It is then moved to a furnace and annealed at 2000 °C. Estimate how long before 10% of the gas trapped in the pellet is released. How many gas atoms/cm³ will have been released during this time? (15 pts)

$f = 6\sqrt{\frac{Dt}{\pi a^2}}$

$t = \frac{f^2}{6^2}\frac{\pi a^2}{D} = \frac{f^2 \pi a^2}{36 D}$

$f = 0.1$

$a = 8 \cdot 10^{-4}$

$D =$

-4, D from wrong temperature, T = 2273 K

$= \frac{(0.1)^2 \pi (8 \cdot 10^{-4})}{36(6.858 \cdot 10^{-19})}$

$= 1.0179 \cdot 10^{12}$ s

Gas released $= N_{fissions} \cdot f = 0.1(3.8057 \cdot 10^{20})$

$= 3.8 \cdot 10^{19}$

Problem 3 (30 points)

-4, 26/30

A ZIRLO cladding tube is in reactor at 600 K for one year. The initial wall thickness is 0.6 mm.

a) What is the oxide weight gain in mg/dm^2 after this time? (10 pts)

$T = 600\,K$

$t = 1\,yr\ (365\,d)$

$\delta = 0.6\,mm$

$\delta^* = 2.039\ \mu m$

$t^* = 295.00$ days

$$\delta = \frac{w}{14.7}$$

after 1 year

$w = \delta \cdot 14.7 =$

$w = (2.039)(14.7) = 29.97$

-0, Your work from part b should be part of this problem, then multiple 2.508*14.7

b) What is the ZIRLO wall thickness after this time? (5 pts)

$\delta = 2.039 + 4.700 \cdot 10^{-3}\,(365 - 295)$

$\delta = 2.508\ \mu m$

$\delta_{initial} - \delta = 0.6 \cdot 10^{-3} - 2.508 \cdot 10^{-6}$

$= 5.9749 \cdot 10^{-4}\ m$

-2, You need to divide thickness by 1.56

c) Assuming the hydrogen pickup fraction is 15%, what is the weight PPM of hydrogen in the cladding after one year? (10 pts)

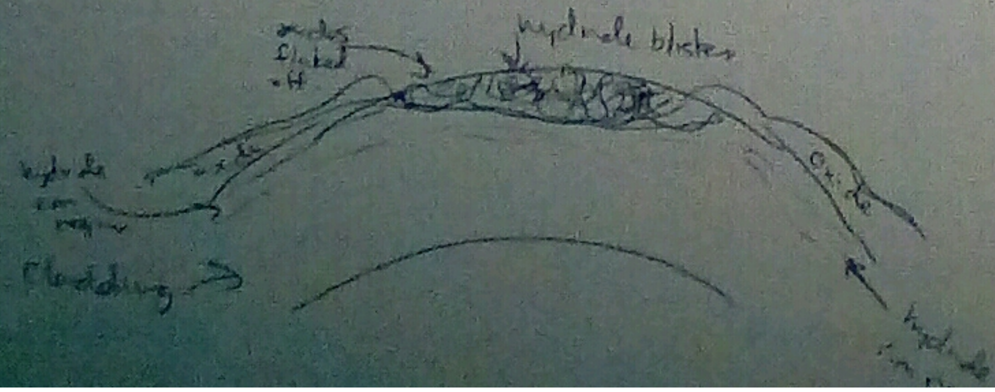
$f = .15$

$$C_H^{clad}\,(ppm) = \frac{m_H}{m_{Zr}} = 2f\,\frac{m_O}{m_{Zr}} = \frac{2f \cdot \delta \cdot C_{ox} \cdot \rho_{ox} \cdot \frac{m_H}{m_O}}{\left(t - \frac{\delta}{PBR}\right) \cdot \rho_{metal}} \cdot 10^6$$

$$\frac{2(0.15)\,(2.508 \cdot 10^{-6})(5.68)(0.26)(1/16)}{\left(5.97 \cdot 10^{-4} - \frac{2.508 \cdot 10^{-6}}{1.56}\right) 6.5} \cdot 10^6 =$$

-2, Answer is 17.87 wt ppm

d) Draw a section of the cladding, showing the various microstructure changes (5 pts)



-3, 12/15

Problem 4 (15 points)

a) What are the primary differences between a loss of coolant accident and a reactivity insertion accident, regarding the fuel and cladding behavior? (5 pts)

Fuel

- fuel dispersal due to pellet cladding interaction (RIA)
- reactivity change (RIA)

Cladding

- Rapid hydrogen pickup (LOCA)
-

-3, RIA is much faster, LOCA changes BC while Ria changes Q

b) What are similarities between the fuel and cladding behavior in a RIA and a LOCA? (5 pts)

Fuel

- fuel dispersal

Cladding

- Burst
- Ballooning

c) List a potential accident tolerant fuel concept and describe how it could meet the primary goal of the accident tolerant fuel program. (5 pts)

A potential ATF concept includes adding silicon carbide layer or additive to UO_2 fuel to increase thermal conductivity, reduce fission product release & lower thermal stress. In reducing fission product release, fuel helps delay or reduce swelling caused by the release, for example, the The gap pressure increase will be delayed. This can delay of PCMI issue leading to fuel dispersal or cladding ballooning + bursting