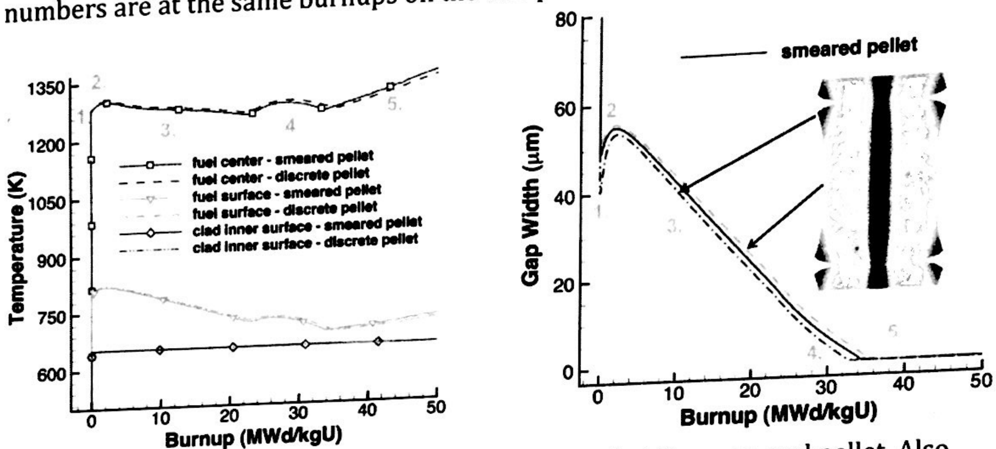
Your exam is very similar to four other students and I suspect cheating, 0/100

NucE 497 Fuel Performance Exam 2 covering modules 4 – 6

Name: 4

-3, 22/25

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. There is no effect on the cladding due to constant temperature. There is a large change in the gap width due to thermal expansion and also thermal expansion occurs in the fuel due to a large increase in the fuel temp.
2. There is no change in the cladding because of the constant temp in the clad inner surface. Densification occurs in the gap causing the gap width to increase. The fuel temp also increases due to densification. The fuel also experiences point defects.
3. Again there is no effect to the cladding due to constant temp. The gap width decreases due to fuel expansion. The fuel decreases slightly due to fission gas moving towards grain boundaries. -1, Swelling, not expansion
4. Creep starts to occur due to the cladding gap becoming close to 0. The gap width is still desreasing and is approaching 0. Creep and fission gas release occur in the fuel. This causes the temp to increase slightly and then decrease slightly in the fuel.
5. At step 5, the cladding is interacting with the fuel. The gap width is 0. The fuel is interacting with the cladding which causes an increase in the fuel center temperature profile.

-2, T increases because fuel conductivity continues to decrease with burnup

Question 2 (30 points) -2. 28/30

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.

$T = 1173.15K$

$K_b = 8.6173\times10^{-5}$

$\dot{F} = 2\times10^{13} \frac{fission}{cm^3 \cdot s}$

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

$D = D_1 + D_2 + D_3 \Rightarrow D_1 = 7.6\times10^{-6} e^{(-3.03/K_bT)} \Rightarrow D_1 = 7.313\times10^{-19} \frac{cm^2}{s}$

$D_2 = 1.41\times10^{-18} e^{(-1.19/K_bT)} \cdot \sqrt{\dot{F}} \Rightarrow D_2 = 4.87\times10^{-17}\ cm^2/s$

$D_3 = 2.0\times10^{-30} \cdot \dot{F} \Rightarrow D_3 = 4\times10^{-17}\ cm^2/s$

$D = 7.313\times10^{-19} + 4.87\times10^{-17} + 4\times10^{-17} \Rightarrow \boxed{D = 8.943\times10^{-17}\ cm^2/s}$

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)

$a = 0.0008cm$

$N_{FG} = YFt \Rightarrow t = 2\,years\left(\frac{365\,days}{1\,year}\right)\left(\frac{24\,hr}{1\,day}\right)\left(\frac{60\,min}{1\,hr}\right)\left(\frac{60\,sec}{1\,min}\right) = 63072000\,sec$

$N_{FG} = (0.3017)(2\times10^{13})(63072000) \Rightarrow N_{FG} = 3.806\times10^{20} \frac{fission\ atoms}{cm^3}$

$f = 1 - \frac{6}{\pi^2} e^{\left(\frac{-\pi^2 Dt}{a^2}\right)} = 1 - \frac{6}{\pi^2} e^{\left(\frac{-\pi^2(8.943\times10^{-17})(63072000)}{(0.0008)^2}\right)} \Rightarrow f = 0.4427$

$f \cdot N_{FG} = \boxed{1.685\times10^{20} \frac{atoms}{cm^3}}$ -2 You used wrong eqn

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)

$T = 2273.15\ K$

$\dot{F} = 2\times10^{13}$

Assuming $\tau < \pi^{-2}$

$f = 0.1$

$D = D_1 + D_2 + D_3$

$D_1 = 7.6\times10^{-6} e^{(-3.03/K_bT)} \Rightarrow D_1 = 1.456\times10^{-12} \frac{cm^2}{s}$

$D_2 = 1.41\times10^{-18} e^{(-1.19/K_bT)} \cdot \sqrt{\dot{F}} \Rightarrow D_2 = 1.45\times10^{-14}\ cm^2/s$

$D_3 = 2\times10^{-30} \cdot \dot{F} \Rightarrow D_3 = 4\times10^{-17}\ cm^2/s$

$D = 1.456\times10^{-12} + 1.45\times10^{-14} + 4\times10^{-17} \Rightarrow D = 1.47\times10^{-12}\ cm^2/s$

$f = 6\sqrt{\frac{Dt}{a^2 \cdot \pi}} - 3\frac{Dt}{a^2} \Rightarrow$ solve for time

$0.1 = 6\sqrt{\frac{Dt}{a^2\pi}} - 3\frac{Dt}{a^2} \Rightarrow \boxed{t = 401.235\ seconds}$

$N_{FG} = 3.806\times10^{20} - 1.685\times10^{20} \Rightarrow N_{FG} = 2.121\times10^{20} \frac{atom}{cm^3}$

$10\% \Rightarrow 2.121\times10^{20}(0.1) = \boxed{2.121\times10^{19} \frac{atom}{cm^3}}$

-6, 24/30

Problem 3 (30 points)

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

T=600K

a) What is the oxide weight gain in mg/dm² after this time? (10 pts)

$\delta^*(\mu m) = 5.1\, e^{(-550/T)} \Rightarrow \delta^*(\mu m) = 2.039$

$t^*(d) = 6.62 \times 10^{-7}\, e^{\left(\frac{11949}{T}\right)} \Rightarrow t^* = 295.01\, days$

$K_L\left(\frac{\mu m}{d}\right) = 7.48 \times 10^{6}\, e^{(-12500/T)} \Rightarrow K_L = 0.0067$

$t = 365\, days$

$\delta(\mu m) = \delta^* + K_L(t - t^*)$

$\delta(\mu m) = 2.508$

$\delta(\mu m) = \frac{w(mg/dm^2)}{14.7} \Rightarrow w(mg/dm^2) = 2.508(14.7) \Rightarrow \boxed{w = 36.867\, \frac{mg}{dm^2}}$

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

initial thickness $= 0.6 \times 10^{3}\, \mu m$

added thickness after 1 year $= 2.508\, \mu m$

Total thickness $= 600 + 2.508 = \boxed{602.508\, \mu m}$

-2, Metal lost = oxide thickness/1.56

-2, ZIRLO thickness is lost, not gained

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

attached

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

-2, Oxide layer?

The hydrides are more concentrated towards areas with high stress and cooler temperatures

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Problem 3 Part C.

$$N_o = \frac{w N_a}{M_o} = \frac{36.87\times10^{-3}(6.022\times10^{23})}{16} = 1.388\times10^{21}\ \frac{\text{oxygen atom}}{dm^2}$$

$$N_H = 2N_o = 2.775\times10^{21}\ \frac{\text{hydrogen atoms}}{dm^2}$$

$$N_{H\text{-}zr} = 2f\cdot N_o = 2(0.15)(1.388\times10^{21}) = 4.163\times10^{20}\ \frac{\text{hydrogen atom}}{dm^2}$$

$$w_H = \frac{N_{H\text{-}zr} M_H}{N_a} = \frac{4.163\times10^{20}(1)}{6.022\times10^{23}} = 6.91\times10^{-4}\,g \text{ of hydrogen in Cladding}$$

$$C_H = \frac{w_H}{w_{zr}} = \frac{w_H}{\rho_{zr} V_{zr}} = \frac{w_H}{\rho_{zr}(t_z A)} = \frac{w_H}{\rho_{zr}\left(t - \frac{\delta_{zro_2}}{PBR}\right)A} \Rightarrow \begin{array}{l}\rho_{zr} = 6.5\\ PBR = 1.56\end{array}$$

$$C_H = \frac{6.91\times10^{-4}}{6.5\left(600 - \frac{2.508}{1.56}\right)(10\times10\times10^{-4})} = 1.77\times10^{-5} = \boxed{17.73\ wt.ppm}$$

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-2, 13/15

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)

In an RIA, the temperature in the fuel spikes upwards faster compared to a LOCA. In a LOCA the cladding changes due to Alpha and beta transition once the cladding temperature rises above 863°C.

-2 In RIA heat production increases while in LOCA heat removal decreases

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

Both in LOCA and in RIA the cladding is likely to balloon. When the fuel temperature increases it can lead to both the fuel breaking apart and/or melting

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)

The simplest modification is to use additives in the UO_2 fuel. This raises the thermal conductivity. Additives such as SiC, BeO, and nano-diamond can be used. These additives result in a lower fuel temp, a reduction in fission product release, and lower thermal stress. This fits the primary goal of the accident tolerant fuel program by making the effects of the fuel safer.