Cole Takasugi 90

Fuel Performance Midterm 2

1) true strain 4/4 accounts for shrinking of the section area and elongation on the further elongation

2) plastic deformation is 6/8 permanent where elastic deformation will undo and return to normal once forces are released

— would have liked a bit more

3) Vacancies, self interstitials, and impurity atoms are 0-D 4/4 since they are at a single point. Precipitate clusters of impurities or large vacant voids can be considered 3D.

4) Melting temperature, thermal conductivity, and processes such as grain growth, gas release, or creep depend on stoichiometry.

6/6

5) The grain size impacts fission gas release, swelling, thermal conductivity and creep - this is largely due to the fact that diffusion often occurs faster along grain boundaries

4/8

~~[illegible]~~ - mechanical properties!

6)

Strain hardening is the result of plastic deformation leading to a permanent strain which may allow higher yield strains when reloaded

4/8

- what causes hardening?
- dislocation pileup, repulsion etc.

7)

1. numerically model temperature in the fuel
2. numerically model stress in cladding
3. consider gap pressure, closure, heat transfer

6/6

3/3

8) Fuel densification occurs as porosity is reduced in the reactor due to ~~irradiation~~ change in free energy from decreased surface area of pores. ✓
Therefore the system is driven toward the lower free energy state

9) Irradiation can accelerate grain growth - this is more significant for small grains at low temperature

6/6

Pores, precipitates, and solute atoms inhibit grain boundary growth by decreasing grain boundary mobility

14/16

10 a) $p = 20\,MPa$ $\bar{R} = 5.4\,mm$
$\delta = 0.8\,mm$

4/4 $\bar{\sigma}_r = -\frac{1}{2}p = -10\,MPa$

$\bar{\sigma}_\theta = \frac{pR}{\delta} = \frac{(20)(5.4)}{(0.8)} = 135\,MPa$

$\bar{\sigma}_z = \frac{pR}{2\delta} = \frac{(20)(5.4)}{1.6} = 67.5\,MPa$

b) $r = \bar{R} = 5.4$, $R_o = 5.4 + 0.4 = 5.8$
$R_i = 5.4 - 0.4 = 5.0$

8/8 $R_o/r = 5.8/5.4 = 1.074$

$R_o/R_i = 1.16$

$\sigma_{rr} = -p\left(\frac{(R_o/r)^2 - 1}{(R_o/R_i)^2 - 1}\right) = -20\left(\frac{(1.074)^2 - 1}{(1.16)^2 - 1}\right) = -8.88\,MPa$

$\sigma_{\theta\theta} = p\frac{(R_o/r)^2 + 1}{(R_o/R_i)^2 - 1} = 20\left(\frac{1.074^2 + 1}{1.16^2 - 1}\right) = 124.62\,MPa$

$\sigma_{zz} = p\frac{1}{(R_o/R_i)^2 - 1} = 20\left(\frac{1}{1.16^2 - 1}\right) = 57.9\,MPa$

2/4 c) $\sigma_{\theta\theta}$ on the inner surface of thick wall would be the same

σ_r? σ_z?

11)

12/12

$$T_0 - T_s = \frac{LHR}{4\pi k} = \frac{250\, W/cm}{4\pi\left(0.1 \frac{W}{cm\,K}\right)} = 198.94\,K$$

$$\sigma^* = \frac{\alpha E (T_0 - T_s)}{4(1-\nu)}$$ ✓

$$= \frac{\left(8.2\times10^{-6}\, \frac{1}{K}\right)\left(2.90\times10^{5}\, MPa\right)\left(198.94\,K\right)}{4(1-0.3)}$$

$$= 168.96\ MPa$$ ✓

$$\sigma_{\theta\theta}^{(\eta=1)} = -\sigma^*(1-3) = 2\sigma^* = 337.9\ MPa$$ ✓

12)

13/16

$$T_0 - T_s = \frac{LHR}{4\pi K}$$

$$\cancel{T_{gap} = T_{clad} + \frac{LHR\, t_{clad}}{2\pi R_{fuel}\, k_{clad}}}$$

$$\cancel{= 450 + (325)(0.02)}$$

$$T_s = T_{\substack{gap \\ (clad\ in)}} + \frac{LHR}{2\pi R_f h_{gap}} \qquad h_{gap} = \frac{k_{gap}}{t_{gap}}$$

$$= 450 + \frac{(325)(0.02)}{2\pi(0.5)(0.1)}$$

$$T_s = 501.73\,K \quad ✓$$

$$T_0 = T_s + \frac{LHR}{4\pi k_f} = 501.73 + \frac{325}{4\pi(0.05)},$$

$$= 1018.98\ K \text{ initially} \quad ✓$$

$$\bar{R}_c = 0.5 + 0.02 = 0.52\ cm$$

$$\bar{R}_f = 0.25\ cm$$

$$\bar{T}_f = \frac{(1018.98 + 501.73)}{2} = 760.355\,K \quad ✓$$

12 continued

$$\Delta\delta_{gap} = R_c\alpha_c(T_c - T_{ref}) - R_f\alpha_f(T_f - T_{ref})$$

$$= 0.52(4.5\times10^{-6})(450-300) - \cancel{0}.25(15\times10^{-6})(760.355-300)$$

R_F

$.5$

$$= -0.001375 \text{ cm}$$

(0.501726 as new R_f)

$$\delta'_{gap} = \cancel{0.0200375} \quad 0.018625 \text{ cm}$$

$$T_s' = T_{cl} + \frac{LHR}{2\pi R_f h_{gap}}$$

$$= 450 + \frac{(325)(0.018625)}{2\pi(0.501726)(0.04)}$$

$$= 498.0 \text{ K}$$

$$T_o' = T_s' + \frac{LHR}{4\pi k_f} = 498.0 + \frac{325}{4\pi(0.05)}$$

$$T_o' = 1015.25 \text{ K}$$ after one expansion

- wrong R in Δt_g makes wrong t_g' + T_o'

13)

8/18

$$\frac{-\sigma_{fr}}{\sigma^*} = 1 - 3\eta^2 \rightarrow 3\eta^2 = 1 + \frac{\sigma_{fr}}{\sigma^*}$$

$$\sigma^* = \frac{\alpha E(T_0 - T_s)}{4(1-\nu)} \qquad T_0 - T_s = \frac{LHR}{4\pi K}$$

$$T_0 - T_s = \frac{200}{4\pi(0.05)} = 318.310$$

$$\sigma^* = \frac{(10.5\times10^{-6}\ 1/K)(210\times10^3\ \text{MPa})(318.310)}{4(1-0.25)}$$

$$= 233.957\ \text{MPa}$$

$$\eta = \sqrt{\frac{1}{3}\left(1 + \frac{120}{233.957}\right)}$$

$$= \sqrt{0.504305} = 0.710443$$

$$\eta = \frac{r}{R_f} \rightarrow r = \eta R_f$$

$$= (0.710443)(0.55\ \text{cm})$$

$$= 0.3906\ \text{cm}$$