Mahmoud Hawary Exam (2)

$\boxed{1}$

$R_f = 4.5\,mm$

$\chi HR = 250\ w/cm$

a) $k = 0.1\ w/cm.K$

$E = 290\ GPa$

$\nu = 0.3$

$\alpha = 8.2 * 10^{-6}\ 1/K$

$\sigma_{max} = ??$

assuming that the max stress is the hoop stress:

$$\sigma_\theta(\eta) = -\sigma^*(1-3\eta^2)$$

where: $\eta = r/R_f$ and $\sigma^* = \frac{\alpha E (T_0 - T_s)}{4(1-\nu)}$

To Calculate σ^* we need to Calculate $(T_0 - T_s)$

$$T_0 - T_s = \frac{\chi HR}{4\pi R_f} = \frac{250}{4\pi * 0.1} = 198.94\ K$$

$$\therefore \sigma^* = \frac{8.2 * 10^{-6} * 290 * 10^3 * 198.94}{4(1-0.3)} = 168.95\ MPa$$

we know that the max hoop stress is at $\eta = 1$ (ppt pg. 28)

where $r = R_f$

$$\therefore \sigma_\theta(\eta = 1) = -168.95(1-3(1)^2) = 337.91\ MPa$$

$$\therefore \sigma_{max} = 337.91\ MPa.$$

b) $\sigma_f = 120$ MPa , crack extension = ?

By solving for (η):

$$\sigma_\theta = \sigma_f = -\sigma^*(1-3\eta^2) \Rightarrow -\frac{\sigma_f}{\sigma^*} = 1-3\eta^2$$

$$\therefore \frac{1}{3}\left(\frac{\sigma_f}{\sigma^*} - 1\right) = \eta^2 \Rightarrow \eta = \sqrt{\frac{1}{3}\left(1+\frac{\sigma_f}{\sigma^*}\right)}$$

$$\therefore \eta = \sqrt{\frac{1}{3}\left(1+\frac{120}{168.95}\right)} = 0.755$$

$$\therefore r = \eta * R_f = 0.755 * 4.5 = 0.57 \text{ mm}$$

$\boxed{2}$ $P = 50\ MPa$

$\bar{R} = 5.4\ mm$

$t_c = 1.2\ mm$

a)

$$\sigma_\theta = \frac{P\bar{R}}{\delta} = \frac{50 \times 5.4}{1.2} = 225\ MPa$$

$$\sigma_z = \frac{\sigma_\theta}{2} = \frac{225}{2} = 112.5\ MPa$$

$$\sigma_r = \frac{-P}{2} = \frac{-50}{2} = -25\ MPa.$$

b) $R_o = \bar{R} + \frac{t_c}{2} = 5.4 + 0.6 = 6\,mm$

$R_i = \bar{R} - \frac{t_c}{2} = 4.8\ mm$

for $(r = 5.6\,mm)$:

$$\sigma_r = -P\frac{\left(\frac{R_o}{r}\right)^2 - 1}{\left(\frac{R_o}{R_i}\right)^2 - 1} = -50\frac{\left(\frac{6}{5.6}\right)^2 - 1}{\left(\frac{6}{4.8}\right)^2 - 1} = 13.15\ MPa$$

$$\sigma_z = \frac{P}{\left(\frac{R_o}{R_i}\right)^2 - 1} = \frac{50}{\left(\frac{6}{4.8}\right)^2 - 1} = 88.8\ MPa$$

$$\sigma_\theta = P\frac{\left(\frac{R_o}{r}\right)^2 + 1}{\left(\frac{R_o}{R_i}\right)^2 - 1} = 50 \times \frac{\left(\frac{6}{5.6}\right)^2 + 1}{\left(\frac{6}{4.8}\right)^2 - 1} = 190.92\ MPa$$

c) Assuming that the max strain will be in the θ-dire.

$$\epsilon_\theta = \frac{1}{E}\left(\sigma_\theta - \nu(\sigma_r + \sigma_z)\right) = \frac{1}{180 \times 10^3}(190.92 - 0.28(13.15 + 88.8))$$

$$= 9.02 \times 10^{-4} = 0.09\ \%$$

3

$R_f = 0.52$ cm , $t_{gap} = 0.005$ cm, $t_{clad} = 0.08$ cm

$k_f = 0.05$ w/cm.K , $k_{gap} = 0.003$ w/cm.K , $T_{co} = 550$ K

$\alpha_f = 15 \times 10^{-6}$ 1/K

$k_{clad} = 0.15$ w/cm.K

$\alpha_c = 4.5 \times 10^{-6}$ 1/K

$LHR = 225$ w/cm

T_{ref} (fuel, clad) = 300 K.

$$\Delta t_{gap} = \bar{R}_c \alpha_c (\bar{T}_c - T_{fab}) - \bar{R}_f \alpha_f (\bar{T}_f - T_{fab})$$

for clad:

$$\bar{R}_c = R_f + t_{gap} + \frac{t_{clad}}{2} = 0.52 + 0.005 + \frac{0.08}{2}$$
$$= 0.565 \text{ cm}$$

To Calculate the change in temp:

$$T_{ci} - T_{co} = \frac{LHR}{2\pi R_f} \frac{t_c}{k_c} = \frac{225}{2\pi \times 0.52} \frac{0.08}{0.15} = 36.72 \text{ K}$$

$$\bar{\bar{T}}_c = 550 + \frac{36.72}{2} = 568.36 \text{ K}$$

$$\Delta t_c = 0.565 \times 4.5 \times 10^{-6} \times (568.36 - 300) = 6.813 \times 10^{-4} \text{ cm}$$

$$T_{ci} - T_{co} = \frac{LHR}{2\pi R_f} \cdot \frac{t_c}{k_c} = \frac{225}{2\pi R_f} \frac{0.08}{0.15} = 36.72 \text{ K}$$

$$T_{ci} = 550 + 36.72 = 586.72 \text{ K}$$

$$T_f - T_{ci} = \frac{225}{2\pi(0.52)} \frac{0.005}{0.003} = 114.77 \text{ K}$$

$$T_f = 586.72 + 114.77 = 701.49 \text{ K}$$

$$T_o - T_F = \frac{225}{4\pi(0.05)} = 358.09\ K$$

$$\therefore T_o = 701.49 + 358.09 = 1059.58\ K$$

$$\therefore \overline{T_f} = \frac{T_o + T_F}{2} = \frac{701.49 + 1059.56}{2} = 880.535\ K$$

$$\therefore \Delta t_F = 0.52 * 15 * 10^{-6} * (880.5 - 300) = 4.52 * 10^{-3}\ cm$$

$$\therefore t_g = 0.005 + 6.813 * 10^{-4} - 4.52 * 10^{-3}\ cm = 1.15 * 10^{-3}\ cm$$

$\boxed{4}$

$a = 8 * 10^{-4}$ cm

$\dot{F} = 2*10^{13}$ fission/cm³ sec

$D = 2*10^{-15}$ cm²/s

# of atoms/cm³ ; $t = 2$ years , $y = 0.3017$.

To determine which equation to be used:

$$\tau = D * \frac{t}{a^2} = 2*10^{-15} \times \frac{2 \times 365 \times 24 \times 60 \times 60}{(8*10^{-4})^2} = 0.1971 > \pi^{-2}$$

$$\therefore f = 1 - \frac{6}{\pi^2} e^{-\pi^2 * 0.1971} = 0.9131$$

total gas released $= f y \dot{F} t = 0.9131 * 0.3017 * 2*10^{13} * (2 \times 365 \times 24 \times 60 \times 60)$

$= 3.47 \times 10^{20}$ atom/cm³.

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Strain hardening is the increase of the stress required to produce the same value of the strain (i.e. the slope of the stress-strain curve in the plastic region is positive).
Strain hardening occurs ~~due~~ mainly due to the increase of the dislocation density. So dislocation will start to interact with each other and imped ~~the~~ motion of each other wich decreases the mobile dislocation density.

6 ① melting temp.
② thermal conductivity
③ grain growth
④ fission gas release

7 ⇒ for fuel:
① Calculate temp profile
② ~ Volumetric change
⇒ for gap:
① Calculate gap heat transport
② ~ the mechanical interaction between fuel and clad
③ ~ the gap pressure.
⇒ for clad:
① calculate temp profile and stress.

8

1 Diffusion of gas atoms to GBs.

2 Growth and interconnection of GB bubbles

3 Transport of gas atoms thru interconnected bubble to a free surface.

9

* Due to the change in the flux profile, we will have strong capture at the periphery of the fuel which will lead to Pu production and increase ~~of~~ in the fissile density. Hence, the burnup also will increase.

* HBS will have a high porosity because of the large number of pores filled with FG, which will degrade the material conductivity and reduce the mean grain size.

10 => 0-D defects => interstials, substitucational, vacancies

3-D defects => Grain boundary, precipitates

11 => for fuel densification => the driving force is the change in the free energy by decreasing the surface area of pores.

=> for grain growth => there are many but the most common is reducing the grain boundary energy.

$\boxed{12}$

valence state for U in UO_2 is U^{4+}. This state can be change due to fission products to U^{5+} and U^{6+}.