(1)

(1) The differences between the true and engineering strain is that true strain accounts for shrinking in the section area and developed elongation on further elongation. Hence the true stain is $\varepsilon_T = F/A$ while $\varepsilon_{engin.} = F/A_0$. In the true stress vs strain curve, there is always an increased of the stress until fracture happen, while the engineering stress it can decreases after the UTS have been reached.

(2) A → No
B → Yes
C → Yes

(3) The differences between elastic and plastic deformation is that in elactic defermation we are stretching the atomic bonds and the material can restore it initial shape and size when the load is removed. However, during plactic defermation the atomic bonds are breaked and the material will ondergo a permanent defermation. the plactic deformation is non-reveruivable.

(4) Examples of 0-D defects are: vacancies, self-interstial atoms and sobstitutional interstial atoms.
Examples of 3-D defects are: precipitak, bubbles, and voids.

(5) - Melting temperature of UO_2
- thermal conductivity
- Lattice constants
- vacancy formation energy

(6) Strain Hardening is the increases or hardening of the materials as it is plastically deformed. During deformation new dislocation will be generated increasing dislocation density. Dislocation will interact with each other and the ones that have equal strain field will hindrace their movement - In average dislocation movement gets more difficult and by (yielding stress) increases. Hence, the matered become stronger.

(7) Fuel code must be able to predict the temperate profile in the fuel and cladding as well as the stress in the cladding. In addition fuel codes also must predic the heat transport in the gap, the gap pressure and the fuel-cladding mechanical interactions

(8) the valence state of U in UO_2 is U^{3+}. the possible valences states of U are U^{4+}, U^{5+}, U^{6+}.

(9) Grain growth can be accelerated by an encrease in temperature. also irradiation can accelerate grain growth at low temperature when the microestructure consist of small grains. On the other hand, pores, precipitates, solute atoms & bubbles can inhibit grain growth

(2)

(10) $P = 20 MPa$

$\bar{R} = 5{,}1 mm$

$t_c = 0{,}6 mm$

a) $\bar{\sigma}_\theta = \frac{P\bar{R}}{\delta} = \frac{20 MPa \cdot 5{,}1 \cancel{mm}}{0{,}6 \cancel{mm}} = 170 MPa$

$\bar{\sigma}_z = \frac{\bar{\sigma}_\theta}{2} = \frac{170 MPa}{2} = 85 MPa$

$\bar{\sigma}_r = \frac{-P}{2} = \frac{-20 MPa}{2} = 10 MPa$

b) $\sigma_r = \frac{-P[(R_o/r)^2 - 1]}{[(R_o/R_i)^2 - 1]}$

$\bar{R} = \frac{R_o + R_i}{2}$ $\Rightarrow$ $5{,}1 mm \cdot 2 = R_o + R_i$

$t_c = R_o - R_i$ $\qquad 0{,}6 mm = R_o - R_i$

$10{,}2 mm = R_o + R_i$

$0{,}6 mm = R_o - R_i$

$10{,}8 mm = 2R_o$

$\boxed{R_o = 5{,}4 mm}$

$\boxed{R_i = 10{,}2 mm - 5{,}4 mm = 4{,}8 mm}$

$\sigma_r(\bar{R}) = \frac{-20 MPa \left[\left(\frac{0{,}54 cm}{0{,}51 cm}\right)^2 - 1\right]}{\left[\left(\frac{0{,}54}{0{,}48}\right)^2 - 1\right]} = -9{,}118 MPa$

$\sigma_\theta = \frac{P[(R_o/\bar{R})^2 + 1]}{(R_o/R_i)^2 - 1} = \frac{20 MPa \left[\left(\frac{0{,}54 cm}{0{,}51 cm}\right)^2 + 1\right]}{\left[\left(\frac{0{,}54}{0{,}48}\right)^2 - 1\right]} = 159{,}706 MPa$

$$\sigma_z = \frac{P}{(R_o/R_i)^2 - 1} = \frac{20\,MPa}{\left[\left(\frac{0,54\,cm}{0,48\,cm}\right)^2 - 1\right]} = 75,294\,MPa$$

c) $$\frac{\cancel{p}\bar{R}}{\delta} = \frac{\cancel{p}\left[\left(\frac{R_o}{r}\right)^2 + 1\right]}{\left[(R_o/R_i)^2 - 1\right]} \rightarrow \text{for } \sigma_\theta$$

$$\frac{\bar{R}}{\delta}\left[(R_o/R_i)^2 - 1\right] - 1 = \left(\frac{R_o}{r}\right)^2$$

$$\frac{R_o}{r} = \sqrt{\frac{\bar{R}}{\delta}\left[(R_o/R_i)^2 - 1\right] - 1}$$

$$\boxed{r = R_o \Big/ \sqrt{\frac{\bar{R}}{\delta}\left[(R_o/R_i)^2 - 1\right] - 1}}$$

$\rightarrow$ at this "r" $\bar{\sigma}_\theta = \sigma_\theta$

for thick wall

for thin wall

(5)

(11) $R_f = 0{,}55cm$

$LHR = 300 w/cm$

$\sigma_0 = ?$

$k = 0{,}12 \frac{w}{cmK}$

$E = 260 \cdot 10^3 MPa$

$\nu = 0{,}3$

$\alpha = 8{,}2 \cdot 10^{-6} \frac{1}{k}$

$\sigma_0 = -\sigma^* (1 - 3\eta^2)$

σ_0 is max at R_0 the $\eta = \frac{r}{R_0} = 1$

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

$T_0 - T_S = \frac{LHR}{4\pi k_f} = \frac{300 w/cm}{4\pi (0{,}12 \frac{w}{cm k})}$

$= 199{,}04 K$

$\sigma^* = \frac{8{,}2 \cdot 10^{-6} \frac{1}{k} \cdot 260 \cdot 10^3 MPa \cdot 199{,}04 K}{4(1-0{,}3)} = 151{,}55 MPa$

$\sigma_0^{MAX} = -151{,}55 MPa (1 - 3(1^2)) = \underline{303{,}11 MPa}$

(12) $R_f = 0{,}5cm$

$t_g = 0{,}02cm$

$T_{CI} = 450K$

$k_f = 0{,}05 w/cmk$

$k_g = 0{,}02 w/cmk$

$k_{clad} = 0{,}18 w/cmk$

$LHR = 320 \frac{w}{cm}$

$\alpha_c = 4{,}5 \cdot 10^{-6} \frac{1}{k}$

$\alpha_F = 9{,}5 \cdot 10^{-6} \frac{1}{k}$

$T_{ref} = 300k$

$T_S - T_{CI} = \frac{LHR\ t_g}{2\pi R_f k_g} = \frac{320 \frac{w}{cm} \cdot 0{,}02cm}{2\pi \cdot 0{,}5 cm \cdot 0{,}02 \frac{w}{cm k}}$

$= 101{,}91 K$

$T_S = 101{,}91 k + T_{CI} = 101{,}91 K + 450K$

$= 551{,}91 K$

$T_0 = \frac{LHR}{4\pi k} + T_S = \frac{320 \frac{w}{cm}}{4\pi \cdot 0{,}05 \frac{w}{cmk}} + 551{,}91 k$

$\boxed{T_0 = 1061{,}46 K}$

⑥

$$\Delta\delta g = \bar{R}_c \alpha_C (\bar{T}_C - T_{ref}) - R_f \alpha_F (\bar{T}_f - T_{ref})$$

$$\bar{R}_c \approx R_f + 0{,}02\,cm = 0{,}5\,cm + 0{,}02\,cm = 0{,}52\,cm$$

do not have 320 w/cm

$$\cancel{T_{CI} - T_{CO} = \frac{CHR\,t_c}{2\pi R_f \cdot K_{cl}}}$$

$$\Delta\delta g = 0{,}52\,cm \cdot 9{,}5 \cdot 10^{-6}\,\frac{1}{k}\,(450\,K - 300\,K) - \left[0{,}5\,cm \cdot 9{,}5 \cdot 10^{-6}\,\frac{1}{k}\,(806{,}68\,K - 300\,K)\right]$$

$$= -2{,}058 \cdot 10^{-3}$$

$$T_f = \frac{T_o + T_s}{2} = \frac{1061{,}46 + 551{,}91}{2} = 806{,}68\,K$$

$$t_g' = 0{,}02\,cm - 2{,}055 \cdot 10^{-3} = 0{,}0179\,cm$$

$$T_s - T_{CI} = \frac{CHR\,t_g'}{2\pi R_f\,k_g} = \frac{101{,}91\,K \cdot 0{,}017}{0{,}02\,cm} = 91{,}2\,K$$

$$\rightarrow 91{,}2\,K + 450\,K$$

$$\boxed{T_s' = 541{,}20\,K}$$

$$T_o' = \frac{CHR}{40\pi k} + T_s' = 509{,}55 + 541{,}20\,K = 1050{,}75\,K$$

$$T_o' = 1050{,}75\,K$$

13

$R_f = 0{,}58\,cm$

$\nu = 0{,}25$

$E = 210\,GPa$

$CHR = 200\,w/cm$

$\alpha_f = 12.5 \cdot 10^{-6} \frac{1}{K}$

$\sigma_f = 140\,MPa$

$K_f = 0{,}04\,w/cm\,K$.

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

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

$$T_0 - T_s = \frac{CHR}{4\pi k} = \frac{200\,w/cm}{4\pi \cdot 0{,}04} = 398{,}08\,K$$

$$\sigma_f^* = \frac{12{,}5 \cdot 10^{-6} \frac{1}{K} \cdot 210 \cdot 10^3\,MPa\,(398{,}08)\,K}{4(1 - 0{,}25)} = 348{,}32\,MPa$$

$$140\,MPa = -348{,}32\,MPa \left[1 - 3\left(\frac{R}{R_f}\right)^2\right]$$

$$\left[\left[\frac{140}{348{,}32} + 1\right]\frac{1}{3}\right]^{1/2} = \frac{R}{R_f}$$

$$\sqrt{0{,}4673} \cdot 0{,}58\,cm = R$$

$$\boxed{R = 0{,}3964\ cm.}$$