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NE 591 - EXAM #2

① Engineering: 4/4 $\sigma = F/A_0$, $\epsilon = (l - l_0)/l$ → calculated with representative length (initial area)

True: $\sigma = F/A$; $\epsilon = \int_{l_0}^{l} \frac{dl}{l} \ln\left(\frac{l}{l_0}\right)$ → calculated with actual area (varying with time)

② 8/8 Elastic deformation is the bond stretching and is not permanent. Plastic deformation is permanent (non-reversible) and caused by deformation in the crystal lattice (slip, twinning)

③ 0D defect. point defect: vacancies, interstitial atoms 4/4

3D defect: cluster of point defects: precipitates (cluster of impurity atoms).

④ - Melting temperature

- Thermal conductivity 6/6

- Chemical reactions at inner cladding surface

⑤ - Fission 3/8 gas release: grain size changes space available within fuel for fission gas

- swelling (same) - not mechanical properties

- Thermal conductivity (depending on - but yes grain size affects these properties/phenomena

⑥ strain hardening is the increase in the yield strain caused by permanent strain in plastic deformation (cause) 4/8

- dislocation pileup, etc.

⑦ ①Fuel centerline temperature, ②stress in the cladding ③consider gap pressure, closure and heat transfer in some way

- temp. profile, not just centerline 6/6

(8) The change in free energy from decrease in surface area of pores and lowering of the surface energy. 3/3

(9) Reduction of grain boundary energy is the most driving force to grain growth, but also T gradients among others. Grain growth is inhibited by pores, precipitations, solute atoms, etc. (impurities) 6/6

(10) $p = 20\ MPa$ $\bar{R} = 5.4mm$ $t_c = 0.8mm$

$= 0.54cm$ $= 0.08cm$

$\bar{R} = R_i + t_c/2 \Rightarrow R_i = 0.54 - 0.04 = 0.5cm$

$R_0 = R_i + t_c = 0.58\ cm$

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a) $\sigma_\theta = \frac{p\bar{R}}{\delta} = \frac{20(0.54)}{0.08} = 142.5MPa$

> equations correct, but some calculator error

$\sigma_z = \frac{p\bar{R}}{2\delta} = \frac{\sigma_\theta}{2} = 71.25\ MPa$

$\sigma_r = -\frac{1}{2}p = -10MPa$

b) at mid point, $r = \bar{R} = 0.54cm$ $\rightarrow \frac{R_0}{\bar{R}} = 1.07,$ $\frac{R_0}{R_i} = 1.16$

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$\sigma_\theta(r) = p\frac{(R_0/r)^2 + 1}{(R_0/R_i)^2 - 1} \Rightarrow \sigma_\theta(\bar{R}) = 20\frac{(1.07)^2+1}{(1.16)^2-1} = 124.13MPa$

$\sigma_z(r) = \frac{p}{(R_0/R_i)^2 - 1} \Rightarrow \sigma_z(\bar{R}) = \frac{20}{(1.16)^2 - 1} = 57.87\ MPa$

$\sigma_r(r) = -p\frac{(R_0/r)^2 - 1}{(R_0/R_i)^2 - 1} \Rightarrow \sigma_r(\bar{R}) = -20\frac{(1.07)^2-1}{(1.16)^2-1} = -8.09\ MPa$

c) The stress in the inside of the wall is $-p$ and on the outside is zero 1/4

- doesn't answer the question

11) $R_f = 4.5mm$ $LHR = 250 W/cm$ $K_f = 0.1 W/cmK$ $E = 290 GPa$ $\nu = 0.3$
$\alpha = 8.2\times10^{-6}\ 1/K$

$$T_0 - T_s = \frac{LHR}{4\pi K_f} = \frac{250}{4\pi(0.1)} = 198.94 K$$

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maximum is σ_θ @ $r = R_f$; $\eta = 1$

$$\sigma^* = \frac{\alpha E (T_0 - T_s)}{4(1-\nu)} = \frac{(8.2\times10^{-6})(290\times10^3)(198.94)}{4(1-0.3)} = 168.96 MPa$$

$$\sigma_\theta = -168.96(1 - 3(1)^2) = \boxed{337.92 MPa}$$

12) $T_{gap} = T_{cI} = 450K$ (assuming)

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$$T_F = T_{gap} + \frac{LHR\ t_{gap}}{2\pi R_f K_{gap}} = 450 + \frac{(325)(0.02)}{2\pi(0.5)(0.04)} = 501.73 K$$

$$T_0 = T_F + \frac{LHR}{4\pi K_f} = 501.73 + \frac{325}{4\pi(0.05)} = 1018.98 K \text{ (before)}$$

$\bar{R}_c = 0.5 + 0.02 = 0.052 cm$

$\bar{T}_c = 501.73 K$ → should be $T_{ci} = 450 K$

$\bar{T}_f = (1018.98 + 501.73)/2 = 760.36 K$

$\Delta\delta_{gap} = (0.052)(4.5\times10^{-6})(501.73 - 300) - (0.5)(15\times10^{-6})(760.36 - 300)$

$\Delta\delta_{gap} = -0.0034 cm$

$t_{g2} = 0.02 - 0.0034 = 0.0166 cm$

$$T_{F_2} = 450 + \frac{(325)(0.0166)}{2\pi(0.5)(0.04)} = 492.93K$$

$$T_{0_2} = 492.93 + \frac{325}{4\pi(0.05)} = 1010.18 K \text{ (after)}$$

(13) $$\sigma^* = \frac{\alpha E(T_0 - T_S)}{4(1-\nu)} = \frac{(10.5\times10^{-6})(210\times10^{3})(1000/4\pi(0.05))}{4(1-0.25)} = 233.96 \text{ MPa}$$

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

$$\frac{-120}{233.96} = 1 - 3\eta^2 \Rightarrow \eta = 0.71 = \frac{r}{R_f}$$

$$\boxed{r = 0.39 \text{ cm}}$$

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