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Problem 1

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		engineering	true
stress	σ	$\frac{F}{A_0}$ ✓	$\frac{F}{A}$ ✓
strain	ε	$\frac{l - l_0}{l_0}$	$\int_{l_0}^{l} \frac{dl}{l} = \ln\left(\frac{l}{l_0}\right)$

→ Engineering stress / strain only takes into account the initial conditions. True stress/strain calculates values using instantaneous conditions

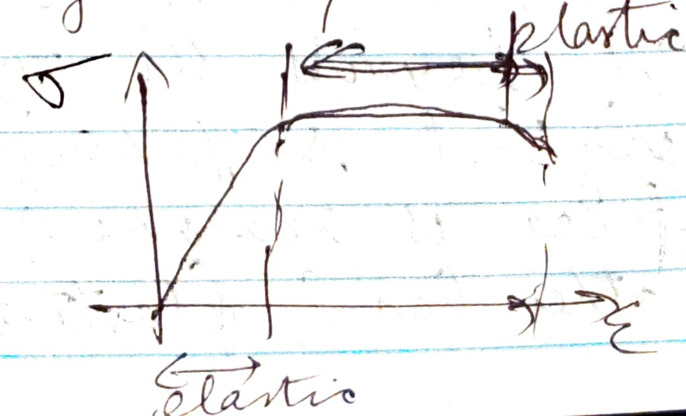
Problem 2

8/8

→ Elasticity is the ability of a body to resist distortion and it reverts the material to original shape/size when force is removed. On the other hand, plasticity is the ability to undergo permanent deformation. So, elasticity is reversible, plasticity is not

— Elasticity is just the stretching of atomic bonds. After releasing the bonds, atoms spring back into original position. But, plasticity is the movements of atoms through many interatomic distances. So after releasing the forces, atoms can't go back as the initial bonds are broken.

— Plasticity is observed in most materials. Also, materials transition from elasticity to plasticity which is known as yielding



Problem 3

4/4

0-D defect	3-D defect
→ Vacancies ✓	→ Voids ✓
→ Substitutional impurity atoms	→ Precipitates

Problem 4

6/6

- → Thermal conductivity ✓
- → Melting temperature ✓
- → Grain growth ✓

Problem 5

4/8 mechanical properties

Grain size affects

- fission gas release
- thermal conductivity
- swelling
- creep ✓

Fission gas is released into the grain ~~the~~ boundaries. So, the size has an impact on the storage of fission gas. Thermal conductivity changes across grain boundaries. So, conductivity becomes a function of grain size. Swelling is directly related to the grain size as well. Grain size also determines grain growth time. So, creep is also dependant on that.

Problem 6

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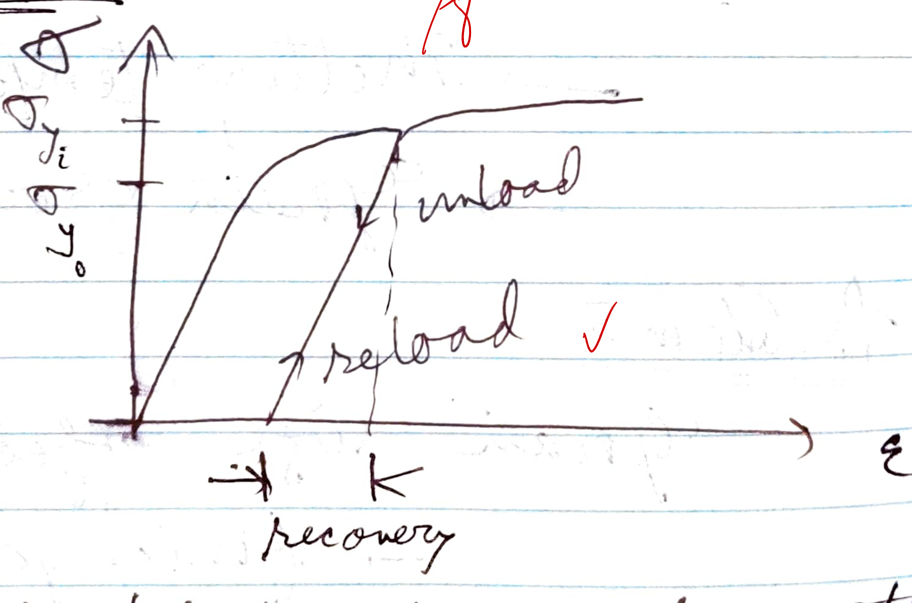

✓

→ After plastic deformation, the material has some permanent strain. So, strain hardening happens when the material is strained beyond yield point. ✓

→ After this deformation, more stress is needed to strain the material. This is the strain hardening of the material as it has become more difficult to deform. ✓

– dislocation pileup and repulsion of disl. leads to hardening

Problem 7

6/6

1. Fuel
   - → temp. profile ✓
   - → volume change
2. Cladding
   - → temp. profile ✓
   - → stress
3. Gap ✓
   - → heat transport
   - → mechanical interaction between clad and fuel
   - → gap pressure

Problem 8

3/3

→ Change in free energy from the decrease in surface area of pores and thus the lowering of the surface free energy.

Problem 9

5/6

accelerator	inhibitor
→ reduction of grain boundary energy	→ pores / particles
→ temp. gradient	→ ~~solutes~~
→ elastic energy gradient	→ precipitates
→ dislocation energy gradient	→ solute atoms or solute drag

1/2

Problem 10

15/16

$p_i = 20$ MPa

$R = 5.4$ mm

$\delta = 0.8$ mm

(a) thin walled

$$\bar{\sigma}_\theta = \frac{pR}{\delta} = \frac{20 \times 5.4}{0.8}$$

4/4

$$\Rightarrow \bar{\sigma}_\theta = 135 \text{ MPa} \checkmark$$

$$\bar{\sigma}_z = \frac{pR}{2\delta} = \frac{20 \times 5.4}{2 \times 0.8} \checkmark$$

$$\Rightarrow \bar{\sigma}_z = 67.5 \text{ MPa}$$

$$\bar{\sigma}_r = -\frac{1}{2}p = -10 \text{ MPa} \checkmark$$

(b) thick walled

8/8

$$\sigma_r = -p \frac{(R_o/r)^2 - 1}{(R_o/R_i)^2 - 1} \checkmark$$

$$\sigma_\theta = p \frac{(R_o/r)^2 + 1}{(R_o/R_i)^2 - 1}$$

$$\sigma_z = p \frac{1}{(R_o/R_i)^2 - 1}$$

Now,

$r = 5.4$ mm

$R_o = 5.8$ mm

$R_i = 5.0$ mm

$\delta = 0.8$ mm

$$\sigma_r = -(20) \frac{(5.8/5.4)^2 - 1}{(5.8/5.0)^2 - 1}$$

$\Rightarrow \sigma_r = -8.89$ ✓ MPa

$\therefore \sigma_\theta = 124.63$ ✓ MPa

$\therefore \sigma_z = 57.87$ ✓ MPa

(c) thin vs thick

3/4

	thin	thick
σ_r	-10	-8.89
σ_θ	135	124.63
σ_z	67.5	57.87

→ σ_r is identical at $\left(\frac{R_0 + R_i}{2}\right)$ — almost

→ σ_θ is identical at R_i ✓

→ σ_z is never identical but almost equal. ✓

12/12

Problem 11

$$\begin{cases} LHR = 250 \ \ W/cm \\ R_f = 4.5 \ \ mm \\ k = 0.1 \ \ W/cm\text{-}K \\ E = 290 \ \ GPa \\ \nu = 0.3 \\ \alpha = 8.2 \times 10^{-6} \ \ K^{-1} \end{cases}$$

$$\Delta T = \frac{LHR}{4\pi k}$$

$$= \frac{250}{4\pi \times 0.1}$$

$$= 198.94 \ K$$ ✓

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

$$= \frac{8.2 \times 10^{-6} \times 290 \times 198.94 \times 10^3}{4(1-0.3)}$$

$$= 168.96 \ MPa$$ ✓

$$\eta = \frac{r}{R_F}$$

For max stress, $\eta = 1$

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

$= -168.96 (1-3)$

$\therefore \sigma_\theta = 337.91$ MPa ✓

8/8

Problem 13

$R_F = 0.55$ cm

$\nu = 0.25$

$E = 210$ GPa

$LHR = 200$ W/cm

$\alpha = 10.5 \times 10^{-6}$ K^{-1}

$\sigma_{fr} = 120$ MPa

$k = 0.05$ W/cm-K

$$\Delta T = \frac{LHR}{4\pi k} = \frac{200}{4\pi \times 0.05} = 318.3\ K$$ ✓

$$\sigma^* = \frac{\alpha E \Delta T}{4(1-\vartheta)}$$

$$= \frac{10.5\times10^{-6} \times 210\times10^{3} \times 318.3}{4(1-0.25)}$$

$$= 233.95 \text{ MPa}$$

Now,

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

$$\Rightarrow 120 = -233.95(1-3\eta^2)$$

$$\Rightarrow \frac{120}{233.95} = 3\eta^2 - 1$$

$$\Rightarrow 3\eta^2 = 1 + \frac{120}{233.95}$$

$$\Rightarrow \eta^2 = \frac{1}{3} + \frac{120}{3\times233.95}$$

$$\therefore \eta = 0.71$$

$$\Rightarrow r = 0.71\, R_F = 0.71 \times 0.55$$

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

12/16

Problem 12

$R_f = 0.5$ cm

$t_g = 0.02$ cm

$T_{ci} = 450$ K

$k_f = 0.05$ W/cm-K

$k_g = 0.09$ "

$k_c = 0.15$ "

$LHR = 325$ W/cm

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

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

$T_{ref} = 300$ K

Equations

$$\Delta \delta_{gap} = \Delta \bar{R}_c - \Delta \bar{R}_f$$

$$\Delta \delta_{gap} = \bar{R}_c \alpha_c (\bar{T}_c - T_{ref}) - \bar{R}_f \alpha_f (\bar{T}_f - T_{ref})$$ ✓

$$T_0 - T_{fuel} = \frac{LHR}{4\pi k_f}$$

$$T_{fuel} - T_{gap} = \frac{LHR\, t_g}{2\pi R_f k_g}$$

$$T_{gap} - T_{clad} = \frac{LHR}{2\pi R_f k_c}$$

$$T_0 - T_f = \frac{325}{4\pi \times 0.05}$$

$$= 517.25 \text{ K}$$

$$T_f - T_g = \frac{325 \times 0.02}{2\pi \times 0.04 \times 0.5}$$

~~= 12.93 K~~ = 51.73 K

$$T_g - T_{cl} = \frac{325 \times 0.02}{2\pi \times 0.5 \times 0.15}$$

$$= 13.79 \text{ K}$$

I assumed, $t_g = 0.02$ cm

– ask next time

~~R_c~~ – Assuming, $t_c = 0.06$ cm

$T_a = T_g = 450\,K$

$\therefore\ T_f - T_g = 51.73\,K$

$\Rightarrow T_f = 501.73\,K$

$\Rightarrow T_o = 1018.98\,K$ ✓

$$\Delta \bar{R}_c = \bar{R}_c \alpha_c (\bar{T}_c - T_{ref})$$

$$= \left(0.5 + 0.02 + \frac{0.06}{2}\right)(4.5 \times 10^{-6})(450 - 300)$$

$$= 3.71 \times 10^{-4}\ \text{cm}$$

$$\Delta \bar{R}_f = \bar{R}_f \alpha_f (\bar{T}_f - T_{ref})$$

– didnt finish