Alex Chrystler NE591 Exam 2 March 18th 2021

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1 True stress accounts for the changing area (cross-sectional) as a material expands/contracts, while engineering stress only accounts for the initial cross-sectional area

This makes true stress constantly increasing, while engineering stress peaks and decreases before the failure point.

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2 Elastic deformation - atomic bonds stretch, but do not break or move. When load is released, the material completely recovers to the original state. In Plastic deformation, bonds break & stretch, atom planes shear. This causes non-reversible shape changes to the material.

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3 A 0-D defect could be a vacancy in an atom lattice, where one atom is entirely absent from the structure.

A 3D defect could be cluster of impurities, particles/other phases trapped in materials, such as secondary particle precipitates in a Zircalloy cladding

4 Fuel Stoicheometry would affect melt temperatures, thermal conductivity of the fuel, and diffusion-dependent properties such as creep and grain growth.

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specifically wanted dislocation discussion

5 Grain size is one part of a fuel's microstructure, which influences properties such as strength, toughness, hardness, corrosion resistance, etc. Average grain size also directly affects fuel swelling, thermal conductivity, creep, and fission gas release by modifying dislocation motion and other atom diffusion.

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6 Strain hardening is the increase of a material's yield strength due to being loaded and unloaded by a force. When you re-load a material, the yield strain is higher than it previously was after strain hardening. This is caused by applying a plastically deforming load and unloading the material prior to failure.

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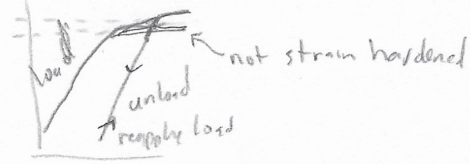
- dislocation pile up + interaction



7 All fuel performance codes must be able to predict temperature profiles & volumetric changes of fuels, Cladding stress & temperature profiles, as well as Gap heat transport, mechanical interaction between fuel and cladding, and gap pressure.

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8 The driving force of fuel densification is the change in free energy due to the decrease in surface area of pores, lowering of the surface free energy. Lowest energy state is most desirable.

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9 Irradiation is one thing that can accelerate grain growth, but only is significant for small grains, low temperatures. Large and spread out temperature gradients can also accelerate grain growth. Grain growth is inhibited by precipitates & soluble atoms.

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a) $\sigma_\theta = \frac{PR}{\delta}$ $\sigma_r = \frac{-P}{2}$ $\sigma_z = \frac{PR}{2\delta}$

$\sigma_\theta = \frac{(20 \text{ MPa})(5.4 \text{ mm})}{(0.8 \text{ mm})} = \boxed{135 \text{ MPa}}$

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$\sigma_r = \frac{-20 \text{ MPa}}{2} = \boxed{-10 \text{ MPa}}$

$\sigma_z = \frac{\sigma_\theta}{2} = \boxed{67.5 \text{ MPa}}$

b) $\sigma_r = \frac{-P\left(\left(\frac{R_o}{r}\right)^2 - 1\right)}{\left(R_o/R_i\right)^2 - 1}$ $\sigma_\theta = \frac{P\left(\left(\frac{R_o}{r}\right)^2 + 1\right)}{\left(R_o/R_i\right)^2 - 1}$ $\sigma_z = \frac{P}{\left(R_o/R_i\right)^2 - 1}$

$R_o = 5.8$ mm
$R_i = 5$ mm
$r = 5.4$ mm

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$\frac{R_o}{r} = \frac{5.8}{5.4} = 1.074$ $\frac{R_o}{R_i} = \frac{5.8}{5} = 116$

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$\sigma_r = \frac{-20[(1.074)^2 - 1]}{(1.16)^2 - 1} = \boxed{-69.65 \text{ MPa}}$ $\sigma_\theta = \frac{20[(1.074)^2 + 1]}{(1.16)^2 - 1} = \boxed{69.65 \text{ MPa}}$

$\sigma_z = \frac{20}{(1.16)^2 - 1} = \boxed{57.87 \text{ MPa}}$

- wrong parentheses leads to wrong answers

c) These assumptions are never identical for ✓ σ_z. For σ_r, they should be identical at the midpoint. For σ_θ, they should be identical ✓ at the inner radius. 3/4

almost...

II $\Delta T = \frac{LHR}{4\pi k} = \frac{250 \text{ W/cm}}{4\pi(0.1 \frac{W}{cm\,K})} = 198.94 \text{ K}$ ✓

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Max stress will always be hoop stress @ $\eta = 1$ ✓

$\sigma_\theta = -\sigma^*[1 - 3\eta^2]$ where $\sigma^* = \frac{\alpha E(\Delta T)}{4(1-\nu)}$ ✓

$\sigma_\theta = \frac{-(8.2\times10^{-6}\frac{1}{K})(290 \text{ GPa})(198.94 \text{ K})}{4(1-0.3)}[1 - 3(1)^2]$ ✓

$= -0.16896[1-3]$

$= 0.33 \text{ GPa} = \boxed{330 \text{ MPa} = \sigma_{max}}$ ✓

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$t_{gap} = 0.02\text{ cm}$

12/16

$$\Delta T_{gap} = \frac{LHR}{2\pi R_F \frac{k_{gap}}{t_{gap}}} = \frac{325\ \frac{W}{cm}}{2\pi(0.5cm)\frac{(0.04\ \frac{W}{cm\,k})}{(0.02\,cm)}} = 51.73\text{ k}$$

$$\Delta T_F = \frac{LHR}{4\pi k_F} = \frac{325\ \frac{W}{cm}}{4\pi(0.05)} = 517.25\text{ k}$$

$$\Delta t_F = (R_F)\,\alpha_F\,(T^F_{avg} - T^F_{ref})$$

$$\Delta t_F = (0.5cm)(15\times10^{-6})(760.36 - 300)$$

$= 0.0035$ cm fuel expansion

Before expansion

Initial $T_{centerline} = 450\text{ k} + 51.73\text{k} + 517.25\text{ k}$

$= 1018.98$ K

$T_{surface\ initial} = 450\text{ k} + 51.73\text{k}$

$= 501.73\text{ k}$

$T^F_{avg} = 760.36$

new $t_{gap} = 0.02 - 0.0035 = 0.0165$ cm

→ clad expansion?

- didn't account for $\alpha_c \Delta T_c R_c$

$$\Delta T_{gap} = \frac{LHR}{2\pi R_F \frac{k_{gap}}{t_{gap}}} = \frac{325\ \frac{W}{cm}}{2\pi(0.5cm)\frac{(0.04\ \frac{W}{cm\text{-}k})}{0.0165\,cm}} = 42.67\text{ k}$$

$$\Delta T_F = \frac{LHR}{4\pi k_F}\ \text{didn't change} = 517.25\text{ k}$$

After expansion

New $T_{centerline} = 450\text{ K} + 42.67\text{k} + 517.2$

$T_{centerline} = 1009.92$ K

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$$\sigma_\theta = -\sigma^*[1 - 3\eta^2] \qquad \sigma^* = \frac{\alpha E \Delta T_F}{4(1-\nu)} \qquad \eta = \frac{r}{R_F}$$

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$$\Delta T_F = \frac{LHR}{4\pi k_F} = \frac{200}{4\pi(0.05)} = 318.31\text{ K}$$

$$= \frac{(10.5\times10^{-6})(210\times10^3\text{ MPa})(318.31)}{4(1-0.25)}$$

$= 935.83$ MPa - didn't divide by 4

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

$$\eta = \left(\frac{\left(1 + \frac{\sigma_{Fr}}{\sigma^*}\right)}{3}\right)^{1/2} = \left(\frac{\left(1 + \frac{120}{935.83}\right)}{3}\right)^{1/2} = 0.6133$$

$1 - 0.6133 = 0.3867$

- right process

cracks propogate 38.67% in from surface of fuel towards center