NucE497: Reactor Fuel Performance

Exam review

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Exam Date:

Mar 2 at 12 am – Mar 3 at 11:59 pm

Total time:

2 hours (Download+Solve+Convert/Upload)

If you create your PDF and then fine something you would like to change, you are permitted to edit your PDF or add notes before submitting. I recommend you have two methods set up to convert your solutions to a PDF, as I will not accept "I couldn't make the PDF" as a valid excuse.

Exam Format

- Exam includes both conceptual and workout problems.
- Conceptual questions include everything discussed in the class.
- Workout problems will be similar to the problems you did on the homework, or that we did in class.
- Make sure and study thoroughly for the exam

Course content

- Module-1: Fuel basics
- Module-2: Heat transport
- Module-3: Mechanical Behavior
- Module-4: Materials issues in the fuel
- Module-5: Materials issues in the cladding
- Module-6: Accidents, used fuel, and fuel cycle

You are responsible for the first three modules…

- Module-1: Fuel basics
- Module-2: Heat transport
- Module-3: Mechanical Behavior
- Module-4: Materials issues in the fuel
- Module-5: Materials issues in the cladding
- Module-6: Accidents, used fuel, and fuel cycle

- # Module-1: Fuel basics

Property	*Metal*	*UO_2*	*UC*	*UN*	*U_3Si_2*
A. Chemical					
Corrosion resistance in water	Very poor	Excellent	Very poor	Poor	Moderate
Compatibility with clad materials	Reacts with normal clad	Excellent	Variable	Variable	Variable
Thermal stability	Phase change at 665 and 770 °C	Good	Good in reducing atmosphere	Good, decomposes at 2600 °C	Good
B. Physical					
Uranium (metal) density (g/cm^3)	19.04	9.65	12.97	13.52	11.31
Melting point (°C)	1132	2865	2850	2860	1665
Thermal conductivity (W/cmK)	0.38 at 430 °C	0.03 at 1000°C	0.25 at 100 – 700°C	0.2 at 750°C	0.23 at 773°C

Volumetric heat generation: $Q[W/cm^3] = E_f N_f \sigma_f \varphi_{th}$

• Module-2: Heat transport

Inc terms of Q

Fuel: $$T_m - T_S = \frac{Q}{4k} R_f^2$$

Gap: $$T_S - T_{CI} = \frac{Q}{2h_{gap}} R_f$$

Cladding: $$T_{CI} - T_{CO} = \frac{Q}{2k_c} R_f \delta_c$$

Coolant: $$T_{CO} - T_{cool} = \frac{Q}{2h_{cool}} R_f$$

In terms of LHR

$$T_0 - T_s = \frac{LHR}{4\pi k}$$

$$T_s - T_{IC} = \frac{LHR}{2\pi R_f h_{gap}}$$

$$h_{gap} = \frac{k_{gap}}{t_G}$$

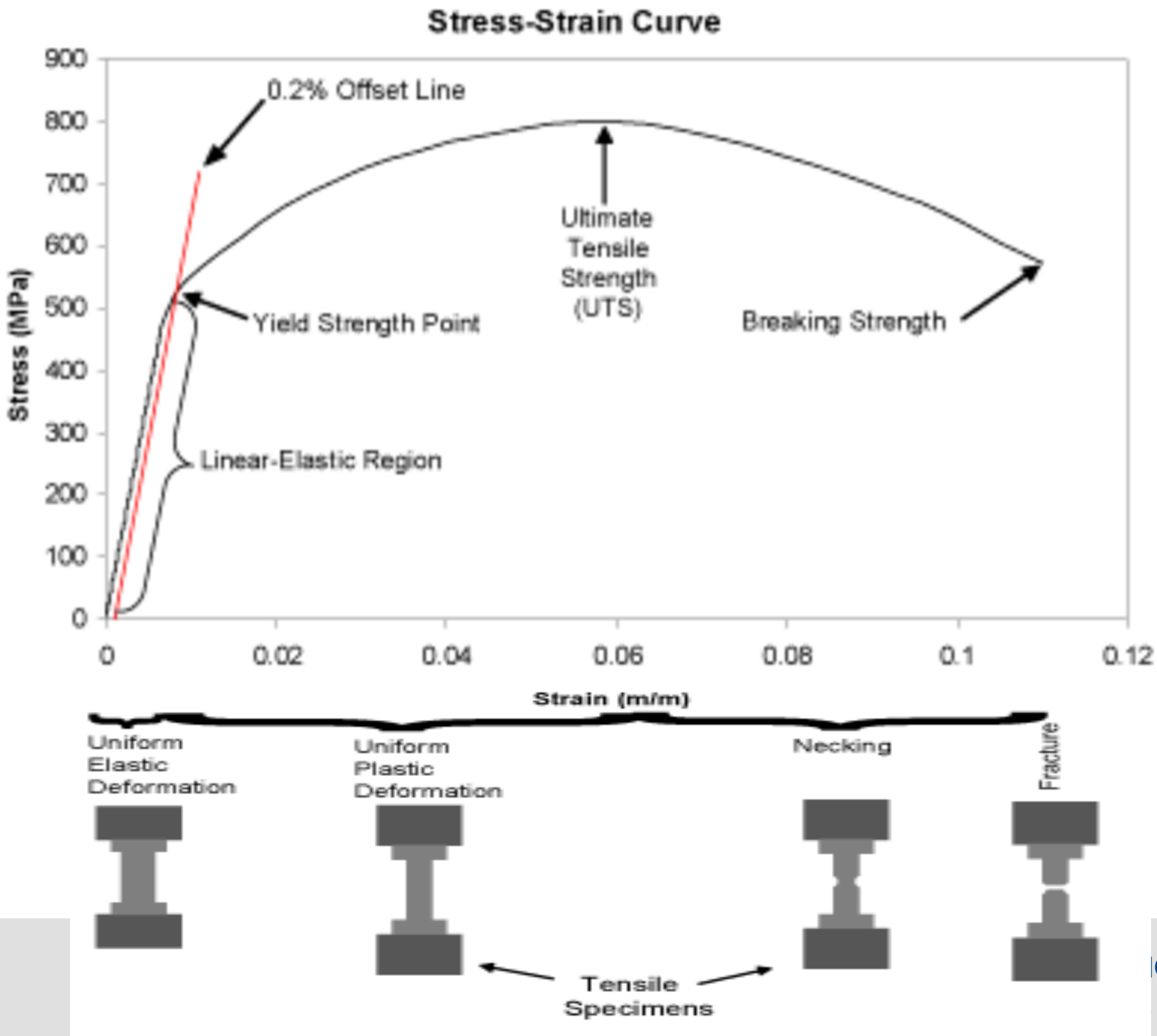
$$T_{IC} - T_{OC} = \frac{LHR\, t_C}{2\pi R_f k_C}$$

$$T_{CO} - T_{cool} = \frac{LHR}{2\pi R_F h_{cool}}$$

<u>Gap thermal conductivity:</u>

$$\left.\begin{array}{l} k_{He} = 16\text{-e6 } T_{ci}^{0.79} \\ k_{Xe} = 0.7\text{e-6 } T_{CI}^{0.79} \end{array}\right\} \quad k_{gap} = k_{He}^{1-y} k_{Xe}^{y}$$

- Module-3: Mechanical behavior



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- Module-3: Mechanical behavior

$$\rho\frac{\partial^2\mathbf{u}}{\partial t^2} = \nabla\cdot\boldsymbol{\sigma} + \rho\,\mathbf{g}$$

  - In this equation, **u** is the displacement vector, ρ is the density, **σ** is the stress, and **g** is the acceleration of gravity.

Assumption-1: Static body,

Assumption-2: Gravity is negligible

Assumption-3: Problem is axisymmetric

Assumption-4: Isotropic material response

$$\epsilon_{rr} = \frac{1}{E}\left(\sigma_{rr} - \nu(\sigma_{\theta\theta} + \sigma_{zz})\right)$$

$$\epsilon_{\theta\theta} = \frac{1}{E}\left(\sigma_{\theta\theta} - \nu(\sigma_{rr} + \sigma_{zz})\right)$$

$$\epsilon_{zz} = \frac{1}{E}\left(\sigma_{zz} - \nu(\sigma_{\theta\theta} + \sigma_{rr})\right)$$

- # Module-3: Mechanical behavior

Thin wall assumption:

$$\overline{\sigma_\theta} = \frac{pR}{\delta} \qquad \overline{\sigma_z} = \frac{pR}{2\delta} \qquad \overline{\sigma_r} = -\frac{1}{2}p$$

Thick wall assumption:

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

- Module-3: Mechanical behavior

If we include thermal stresses result from thermal gradient

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

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

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

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

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