83/100

Hunter Thompson NucE 497 Test 1

1. $K = 0.125$ [$\frac{W}{cm K}$] , $\rho_U = 7.5 g\ U/cm^3$ -3, 27/30

a) The fissile isotope in U_3Si_5 is Uranium-235, which forms approximately 0.7% of natural Uranium. ($\rho_U(U_3Si_2 = 11.31)$)

b) $Q = E_f N_f \sigma_f \phi_{th}$ [$J/s/cm^3$] , $\phi_{th} = 3.2\times10^{13}\ \frac{n}{cm^2 s}$,

$$N_{235} = \frac{q_{235}\rho_U N_A}{M_{235}} = \frac{0.03(11.31\ g/cm^3)(6.022\times10^{23})}{235} = 8.695\times10^{20}\ atoms/cm^3$$

($\rho_{U-U_3Si_2}$)

$$Q = (3\times10^{-11}\ J/fission)(8.695\times10^{20})(5.5\times10^{-22})(3.2\times10^{13}) = 459.08\ W/cm^3$$

$$N_f = 8.695\times10^{20}\ atoms/cm^3 = \frac{q_{235}(7.5 g/cm^3)(6.022\times10^{23})}{235}$$

($\rho_{U-U_3Si_5}$)

$\boxed{q = 4.52\%}$

c) I would consider U_3Si_5 to be an inferior choice for a fuel compared to U_3Si_2 because a higher enrichment is required to achieve the same energy release rate. Therefore, U_3Si_5 would be more expensive.

-3, thermal conductivity?

2. $R_f = 0.45 cm$, $t_G = 0.008 cm$, $t_c = 0.06 cm$, $LHR = 250\ \frac{W}{cm}$, $T_{cool} = 580 K$, 5% Xe

$h_{cool} = 2.5\ W/cm^2K$, $K_c = 0.17\ W/cm\text{-}K$ -1, 34/35

a) $T_{co} = T_{cool} + \frac{LHR}{2\pi R_f h_{cool}} = 580 K + \frac{250}{2\pi(0.45)(2.5)}$ $T_{co} = 615.37 K$

$T_{ci} = T_{co} + \frac{LHR\, t_c}{2\pi R_f K_c} = 615.37 + \frac{250(0.06)}{2\pi(0.45)(0.17)}$ $T_{ci} = 646.58 K$

$h_{gap} = \frac{K_{He}^{1-0.05} K_{Xe}^{0.05}}{t_G} = \left(\left[\underbrace{16\times10^{-6}(646.58)^{0.79}}_{0.003575}\right]^{0.95}\left[0.7\times10^{-6}(646.58)^{0.79}\right]^{0.05}\right)/0.008$ $h_{gap} = 0.284$

$T_s = T_{ci} + \frac{LHR}{2\pi R_f h_{gap}} = 646.58 + \frac{250}{2\pi(0.45)(0.284)}$ $\boxed{T_s = 957.92 K}$

b) UN, $E = 246.7 GPa$, $\nu = 0.25$, $\alpha = 7.5e^{-6}\ \frac{1}{K}$, $K = 0.2$

$T_m = T_s + \frac{LHR}{4\pi K} = 957.92 + \frac{250}{4\pi(0.2)}$ $T_m = 1057.39 K \rightarrow \Delta T = T_m - T_s = 99.47 K$

Max Stress: hoop stress at fuel radius $r = R_f$: $\sigma^* = \frac{\alpha E \Delta T}{4(1-\nu)} = \frac{7.5\times10^{-6}(246.7\times10^3 MPa)(99.4)}{4(1-0.25)} = 61.3 MPa$

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$\sigma_{\theta\theta}(\eta) = -\sigma^*(1-3(\frac{R_f}{R_f})^2) = -61.3\ MPa\,(1-3)$ $\boxed{\sigma_{\theta\theta} = 122.6\ MPa}$

c) The stress would be higher in UO_2 because UO_2 has a much lower thermal conductivity. Thus, the temperature difference in the fuel will be greater, causing more stress.

d) Assumptions: 1. Static body
2. Gravity is negligible
3. Axisymmetric
4. Isotropic material response.

-1, There are several more assumptions

3. Zircalloy fuel rod, $p = 6MPa$ $\bar{r} = 0.56\ cm$, $t_c = 0.06\ cm$

-13, 22/35

a) Assumptions: 1. Very thin wall (radius is much larger than thickness)
2. Uniform internal pressure
3. Symmetric

-3, stress is constant across radius

b)
$$\bar{\sigma}_\theta = \frac{pR}{t_c} = \frac{6(0.56)}{0.06} \qquad \bar{\sigma}_\theta = 56\ MPa$$
$$\bar{\sigma}_z = \frac{pR}{2t_c} = \frac{6(0.56)}{0.12} \qquad \bar{\sigma}_z = 28\ MPa$$
$$\bar{\sigma}_r = -\frac{1}{2}p = -\frac{1}{2}(6) \qquad \bar{\sigma}_r = -3\ MPa$$

c) Actual radius $= 0.56cm \pm 0.03\ cm \rightarrow R_i = 0.53cm,\ R_o = 0.59\ cm$

-3, Compute stress at TWO radii to see if it is constant across thickness

Thick wall: $\bar{\sigma}_{\theta\theta}(r=0.56) = p\frac{(R_o/0.56)^2+1}{(R_o/R_i)^2-1} = 6MPa\,\frac{2.110}{0.239}$ $\underline{\sigma_{\theta\theta} = 52.91\ MPa}$

based on the thick wall calculation is 3.08 MPa less than the thin-wall approximation. It is conservative, as it predicts an earlier failure time.

d) $\sigma = \begin{bmatrix} 70 & 0 & 0 \\ 0 & 70 & 0 \\ 0 & 0 & 70 \end{bmatrix}$ GPa $\qquad \varepsilon = \frac{1}{70}\begin{bmatrix} 1 & -0.41 & -0.41 \\ -0.41 & 1 & -0.41 \\ -0.41 & -0.41 & 1 \end{bmatrix}$

-2, Stress should be from part b
-5, Compute strains from stress from part b