EXAM #1 | NE 533 | Jess Williams

(1) Derive relationship for temp drop in cartesian

$T'(x_0) = 0 \quad x_0 = 0 \quad x_1 = X \quad T(x_1) = T_1$

$$\frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) + Q = 0$$

assume SS, axisymmetric, constant in z, + const. thermal conductivity

$$\frac{d}{dr}\left(rk \frac{dT}{dr}\right) = -Qr$$

$$\frac{dT}{dr} = \frac{-Qr}{2k}$$

$$T(r) = -\frac{Qr^2}{4k} + C_2 \qquad r^2 = x^2 + y^2$$

$$T(x,y) = -\frac{Q(x^2+y^2)}{4k} + C^2$$

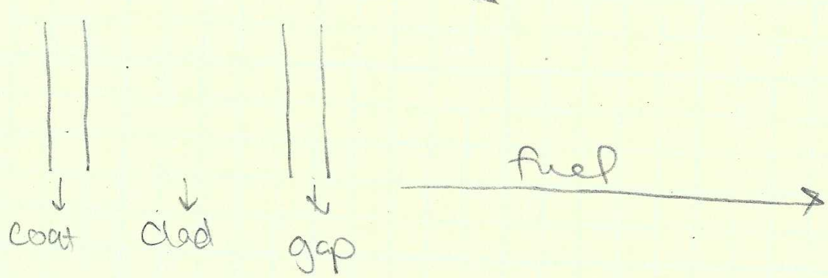
② Compute fuel centerline temp w/ + without coating

$K_{coat} = 0.015$
$K_{clad} = 0.15$
$K_{fuel} = 0.05$
$k_{gap} = 0.004$

$T_{coat, out} = 600K$
$Q = 250\ W/cm^3$
$R_F = 0.6\ cm$

$t_{gap} = 0.005$
$t_{clad} = 0.05$
$t_{coat} = 0.01$

T_{co} w/o clad $= 600K$



Assume coating linear temp profile

with

$$T_{oc} - T_{coat} = \frac{LHR\ t_{coat}}{2\pi R_f k_{coat}} \qquad LHR = \pi R_f^2 Q_{av}$$

$$LHR = \pi(0.6)^2(250) = 282.743$$

$$T_{oc} = \frac{LHR\ t_{coat}}{2\pi R_f k_{coat}} + T_{coat} = \frac{282}{2\pi(0.6)} \frac{(0.01)}{(0.015)} + 600 = 650$$

$$T_{ic} = \frac{LHR}{2\pi R_f} \frac{t_{clad}}{k_{clad}} + T_{oc} = 675K$$

$$T_f = \frac{LHR}{2\pi R_f} \frac{t_{gap}}{k_{gap}} + T_{ic} = 768K$$

$$T_o = \frac{LHR}{4\pi K_{fuel}} + T_{fuel} = 1218K$$

without

$$T_{ic} = \frac{LHR}{2\pi R_f} \frac{t_{clad}}{k_{clad}} + T_{oc} = 625$$

$$T_f = \frac{LHR}{2\pi R_f} \frac{t_{gap}}{k_{gap}} + T_{ic} = 718$$

$$T_o = \frac{LHR}{4\pi k_{fuel}} + T_f = 1168k$$

T_o, with coat $= 1218K$
T_o without coat $= 1168k$

③ UN $x = 19.5\%$ $\rho = 12.3\ g/cm^3$ $\sigma_f = 570$

$Z_N = 14$

a) Wat Q given $\phi = 5\times10^{12}\ n/cm^2 s$

$Q = E_f N_f \sigma_f \phi$ $E_f \sim 200\ eV \times 1.602e{-19}\ J/eV = 3.204\times10^{-17}$

Molar mass UN $= (235\cdot 0.195) + (238\cdot 0.805) + 14$
$= 251.415\ g/mol$

$N_f = 12.3 \times \left(\frac{6.022e23}{251.415}\right) \times \left(\frac{1}{1}\right) \times (0.195)$
$= 5.745\times10^{21}$

$Q = (3.204\times10^{-17})(5.745\times10^{21})(570e{-24})(5e12)$

$Q = 5.246\times10^{-4}$

b) $N_f = \frac{Q}{E_f\ \sigma_f\ \phi} = 5.745\times10^{21}$

$N_f = 10.97\left(\frac{6.022e23}{mm}\right)(x_f)$

$\frac{x_f}{mm} = \frac{5.745\times10^{21}}{10.97\times 6.022e23} = 0.00869\ldots$

$\frac{x_f}{235x_f + 238(1-x_f)} = 0.00869$

$x_f \sim 0.206$

④ $L = 3.5\,m$ $LHR^{\circ} = 350$ $\gamma = 1.3$

a) LHR @ $z = 1.4$

$$LHR\left(\frac{1.4}{3.5}\right) = (350)\cos\left(\frac{\pi}{2(1.3)}\left(\frac{1.4}{3.5} - 1\right)\right)$$
$$= 261.979$$

b)

$$T_{cool} - T_{cool}^{in} = \frac{1}{\dot{m}C_{pw}}\, z_0 \times LHR^{\circ} \int_0^{z/z_0} \cos\left[\frac{\pi}{2\gamma}\left(\frac{z}{z_0} - 1\right)\right] dz$$

⑤ $\frac{dy}{dt} = t e^{-2t}$ $t_0 = 0$ $y_0 = 4$

(6) Fissile isotopes are isotopes that readily undergo fission in the thermal neutron energy range. Fertile isotopes are isotopes that transmute to fissile isotopes by capturing neutrons. Fissionable isotopes are isotopes that only readily fission with fast spectrum neutrons

(7) Pure metallic U is undesirable as a fuel because it has a low melting point + is susceptible to significant swelling

(8) Smear density is the ratio of the fuel volume to the total internal volume of the fuel element. This is necessary to accurately depict how much of the entire fuel element is actually fuel vs other non-fissile materials.

(9) U-235 is a naturally occurring fissile isotope that only makes up 0.7% of natural uranium. For use in most reactors, uranium must be enriched to higher concentrations of U-235 (3-5%) to sustain fission reactions. Uranium is enriched as gaseous UF_6.

Centrifuge-based enrichment spins the UF_6 gas at high speeds to seperate the U-235 from the U-238. U-238 is slightly heavier then U-235 so the centrifugal force forces the U-238 further toward the outside then the U-235. The gas can be siphoned off at the center to pull out the slightly higher enriched gas. This process must be repeated several times until the desired U-235 concentration is achieved.

(10) The three ways space is discretized are: (1) finite difference; (2) finite volume; and (3) finite element. The finite difference method is simple + fast computationally, but it is difficult to use with complex geometries + BCs

(11) Departure from nucleate boiling is when the hottest channel in a reactor exceeds the critical heat flux that causes dryout which greatly reduces the ability of the coolant to remove heat from the fuel + can cause the clad + fuel to exceed safe temperatures.

The critical heat flux is the point at which the coolant transitions from nucleate boiling to transition boiling.

(12) The layers from inside to outside of TRISO Fuel

1) Fuel kernel
2) Buffer
3) Inner pyrolitic Carbon
4) SiC
5) Outer pyrolitic Carbon

Reactors That use This type of fuel include High Temperature Gas Reactors