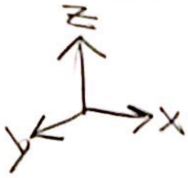
ii.



① ① $T'(x_0) = 0$, $x_0 = 0$

② $x_1 = x$, $T(x_1) = T_1$

CARTESIAN COORDINATES

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

Assume:

* k = Constant i.e. $k \neq$ func of x
* Temp does not vary along y, z (i.e symmetric about y, z)
* steady state (SS) $\rightarrow \partial/\partial t(\;\;) = 0$
* Q is invariant with x (i.e. constant)
* fuel is rectangular or box shaped

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

$$\int \partial \left(\frac{k\partial T}{\partial x}\right) = -\int Q \, \partial x$$

$$k \frac{\partial T}{\partial x} = -Qx + C_1$$

using BC #1 $\rightarrow C_1 = 0$

$$\int k \, \partial T = \int [Qx] \partial x$$

$$kT(x) = -\frac{Qx^2}{2} + C_2$$

use BC #2 - $T(x_1) = T_1$

$$kT_1 = -\frac{Qx_1^2}{2} + C_2$$

a LHR^0 = 15... inlet temperat...

$$C_2 = kT_1 + \frac{QX_1^2}{2}$$

so

$$kT(x) = -\frac{QX^2}{2} + kT_1 + \frac{QX_1^2}{2}$$

$$k(T(x) - T_1) = \frac{Q}{2}[X_1^2 - X^2]$$

$$\boxed{T(x) = \frac{Q}{2k}[x_1^2 - X^2] + T_1}$$

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② Calc centerline T & $T(r=0.4\,cm)$

$k_{coat} = 0.05\ W/cmK$, $k_{clad} = 0.15\ W/cmK$, $k_{gap} = 0.25\ W/cmK$
$k_{fuel} = 0.005\ W/cmK$

$h_{cool} = 5.5\ W/cm^2 \cdot K$ $\quad$ $1\,cm = 0.01\,m$
$T_\infty = 800\,K$
$Q = 400\ W/cm^3$

$$T_{\cancel{coat}}^{out} = T(r_4) = \frac{Q}{2\,h_{cool}} R_{fuel} + T_\infty$$

$$T_4 = \frac{400\ W/cm^3}{(2)(5.5\ W/cm^2 \cdot K)}(0.6\,cm) + 800\,K$$

$$\underline{T_4 = 821.82\,K}$$

$$T_3 = \frac{Q\,t_{coat}}{2\,k_{coat}} R_f = \frac{(400)(0.01)(0.6)}{2 \times 0.05} + T_4$$

$$\boxed{T_3 = 845.82}$$

$$T(r_2) = T_2 = \frac{Q\,\cancel{t_{clad}}}{2\,k_{clad}} R_f + T_3$$

$$= 847.32\,K$$

$$T_1 = T(r_f) = \frac{Q\, t_{gap}}{2 k_{gap}} R_f + T_2$$

$$T_1 = 1007.32\ K$$

$$T_0 = \frac{Q}{4 k_{fuel}} R^2_{fuel} + T_1$$

$$\boxed{T_0 = 8207.32\ K}$$

at $r = 0.4$ cm

$$\boxed{T(0.4\ cm)} = \frac{Q\,(0.6^2 - 0.4^2)}{4 \times k_{fuel}} + T_1$$

$$= 5007.32\ K$$

Calculating heat generation rate for a given fu

about 200 MeV of energy is available due to a fission (210 MeV

section of the target nuclide (tabulated)

density

($\dot{\phi}$), Temp, fuel, etc.

ity, σ_f is the

that fission is

0.145 W/cm K

③ $k_{fuel} = 14.5$ W/mK $E = 0.195$

$\rho_{fuel} = 15.67$ g/cm³

$\sigma_f = 5.7 \times 10^{-22}$ cm²

a) $\dot{\phi} = 2\times10^{12}$ n/cm²·s

$Q = E_f N_f \sigma_f \dot{\phi}$

$$N_f = \frac{\rho_{fuel} \; N_A \; E}{235E + 238(1-E) + 2\times16}$$

$$= \frac{15.67 \times 6.023\times10^{23} \times 0.195}{269.77}$$

$$= 6.82\times10^{21} \; \frac{U^{235}\text{ atoms}}{cm^3}$$

$$E_f = \frac{200\times10^6 \text{ eV}}{\text{fission}} \times 1.602\times10^{-19} \text{ J/eV}$$

$= 3.2\cancel{1}8 \times 10^{-11}$ J

$\boxed{Q = 250.6 \text{ W/cm}^3}$

b) using excel to change enrichment

for $\rho = 10.97$ g/cm³,

$\boxed{E = 0.2784 \text{ or } 27.84\%}$

NC STATE UNIVERSITY

Calculating heat generation rate for a given fuel

...V of energy is available due to a fission (210 MeV ... (tabulated)

4

a) $LHR(z=1.8\ m)$

$LHR^{\circ} = 150\ W/cm\,K \Rightarrow 1.5\times10^{4}\ W/m\,K$

$z_0 = \frac{L}{2} = 1.5\ m$

assuming radians

$LHR^{\circ} = LHR(1.5\ m)$

$LHR(1.8/1.5) = (1.5\times10^{4}\ W/m\,K)\cos\left(\frac{\pi}{2.2}\left(\frac{1.8}{1.5}-1\right)\right)$

$\boxed{LHR(1.8\ m) = 1.44\times10^{4}\ W/m\,K}$

b) $\Delta T = \frac{1}{1.43}\frac{z_0\,LHR^{\circ}}{\dot m\,c_{pw}}\left(\sin(\underset{\pi/2\times1.1}{1.43}) + \sin(1.43 \ldots\right.$

$\Delta T_i = 17.3 \times$ { " $\sin(1.43$ ")
$= 16.86$

$\Delta T_{ii} = 93.39$ { " ")
$= 92.47$

$\boxed{\Delta T_{ii} > \Delta T_i}$

⑤ $y(t_0) = 6 = y(1)$ $\quad t_n = 2$

$y'(t) = 4t - 3t^2$ $\quad dt = 0.33$

Fwd Euler

$y(t_1) = y(t_0) + \Delta t\, y'(t_0)$

$t_0 = 1$
$t_1 = t_0 + dt = 1.33$
$t_2 = t_1 + dt = 1.66$
$t_3 = t_2 + dt = 1.99 \approx 2$

$y(t_0) = 6$
$y(t_1) = 6.33$
$y(t_2) = 6.3343$
$y(t_3) = 5.798$

$y(t_1) = 6 + 0.33 \times (4(1) - 3(1)^2)$

$y(t_2) = y(t_1) + 0.33 \times (4 \times (1.33) - 3(1.33)^2)$

$y(t_3) = y(t_2) + 0.33\,(4 \times 1.66 - 3(1.66)^2)$

$y(t_4) = y(t_3) + 0.33\,(4 \times 1.99 - 3 \times 1.99^2)$

Bckward Euler

$y(t_1) = y(t_0) + dt * y'(t_1)$

or

$y^{n+1} = y_n + dt * y'_{n+1}$

$y_1 = 6 + 0.33 \times (4 \times 1.33 - 3 \times (1.33)^2)$

Backward
$y_0 = 6$
$y_1 = 6.0043$
$y_2 = 5.467$
$y_3 = 4.174$

(6) Fissionable - can undergo fission @ high or low neutron energy
Fertile can become fissile via transmutation

fissile - able to undergo fission w/ low energy neutron

(7) (1) many phases α, γ, β
(2) α-U shrinks in 1-D & expands along other 2-directions (thermally unstable)

(8) Smear density is ratio of fuel mass to total volume w/in fuel rod. It is used to compare the relative swelling of fuels

(10) ^{96}Rb & ^{144}Xe

$${}^{1}_{0}n + {}^{235}U \rightarrow {}^{236}U \rightarrow {}^{144}Xe + {}^{90}Sr + 2\,{}^{1}_{0}n$$

$${}^{1}_{0}n + {}^{235}U \rightarrow {}^{236}U \rightarrow {}^{96}Rb + {}^{137}Cs + 3\,{}^{1}_{0}n$$

(11) 3 space discretization methods

Finite element

Finite difference

Finite volume
all 3 used in state of art codes

Finite difference was the 1st method developed

Finite volume is very useful when flux is approx. equal @ interfaces.

Finite volume is most flexible & useful in complex geometries but very intricate so not used when not needed

(9) We enrich U to increase fissile atoms in fuel. UF_6 is used in centrifuge process. The difference in isotopic mass allows separation by centrifugal force i.e. ^{238}U gets pushed to outside of centrifuge container & allows ^{235}U to be drawn out from center.

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