

Nuclear Reactor Physics Lecture Note (8)

-Core Burnup(2) Burnup Calculation, Reactivity Control, Reactivity Feedback-

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4.2 Fuel burnup analysis

(1) Burnup equation

Change of fuel composition during reactor operation

Decrease of fissile nuclide (^{235}U , ^{239}Pu , etc.)

Decrease of fertile nuclide (^{238}U , etc.)

Decrease of burnable poison (B, Gd, etc.)

Production of trans uranium elements(TRU) (Pu, Cm, Am, etc.)

Production of fission products (FP) (Xe, Sm, etc)

General form of burnup equation

$$\frac{dN_A}{dt} = -\lambda_A N_A - \sigma_a^A \phi N_A + \lambda_B N_B + \sigma_A^C \phi N_C$$

B : nucleus whose atomic number is one smaller than nucleus A

C : nucleus whose mass number is one smaller than nucleus A

Simultaneous equations of burnup equation are solved for each nucleus.

(2) General procedure of burnup calculation

(3) Burnup (Index of fuel burnup)

Definition : (Produced energy during operation) / (total mass of initial uranium)

Unit : MWd/t-U (Mega-Watt-days per Ton Uranium)

Fission energy of 1g of fissile nuclide is about 1MWd.

Burnup of typical power reactor ($10^4 \sim 10^5 \text{ MWd/t-U}$) corresponds burnup of 1~10% of the uranium.

ex. LWR $30000 \sim 40000 \text{ MWd/t-U} = \text{Burnup of } 3 \sim 4\% \text{ of uranium}$

5. Reactivity control

(1) Method to control reactivity

① Control rods ex. Cd, B, Hf(hafnium)

② Burnable poison

To compensate the excess reactivity of initial core, neutron absorbing materials are loaded in the core.

③ Chemical shim (PWR only)

Boronic acid is dissolved in the coolant for reactivity control.

(2) Reactivity effect

Temperature coefficient α_T

$$\alpha_T \equiv \frac{\partial \rho}{\partial T} = \frac{1}{k^2} \frac{\partial k}{\partial T} \cong \frac{1}{k} \frac{dk}{dT}$$

If the fuel temperature coefficient is α_T^F , the moderator temperature coefficient is α_T^M ,

then

$$\alpha_T = \frac{1}{k} \frac{\partial k}{\partial T_F} + \frac{1}{k} \frac{\partial k}{\partial T_M} = \alpha_T^F + \alpha_T^M$$

Fuel temperature coefficient : Doppler effect of resonance absorptions

Moderator temperature coefficient : Spectrum shift of thermal neutrons

Examples of other reactivity effects

Coolant void coefficient (sometimes positive in fast reactors)

Expansion coefficient