Nuclear Reactor Physics Lecture Note (7)

-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（10^4～10^5MWd/t-U）corresponds burnup of 1～10% of the uranium.

ex. LWR　30000～40000 MWd/t-U＝Burnup of 3～4% of uranium

5. Reactivity control

5.1 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.

5.2 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