22.251 Systems Analysis of the Nuclear Fuel Cycle

Fall 2009

Lab #4: MCNP PWR Pin Cell Model

A typical PWR unit cell MCNP model is provided in /dsk2/users/251/MCNP.EXAMPLE/uo2.inp on mightyalpha.mit.edu machine. It models the geometry of representative PWR lattice cell with 4.5 w/o enriched fuel. Typical parameters are:

Fuel (UO_2) Enrichment	4.5 w/o
Fuel (UO_2) Density	10.4 g/cm3
Lattice Pin Pitch	1.26 cm
Fuel Temperature	900 K
Pellet Radius	0.4096 cm
Gap Thickness	0.0082 cm
Rod Diameter	0.9500 cm
Water Temperature	583.1 K
System Pressure	15.5 MPa
Power Density	104.5 kW/liter-core

(a) Using the given MCNP model, run MCNP and calculate the following reaction rates (tally F4)

U-235 fission rate (use FM = −6)

U-238 capture rate (use FM = 102)

In addition, assume the two group model takes the boundary of 0.625 eV, and calculate the epithermal and thermal components of each reaction. Compute spectrum indices based on these reaction rates:

Ratio of U-238 captures to U-235 fissions	C^*
Ratio of epithermal U-235 fissions to thermal U-235 fissions	δ_{25}
Ratio of epithermal U-238 captures to thermal U-238 captures	ρ_{28}

(b) Calculate and plot the neutron spectrum inside the fuel pellet in 300 equal lethargy groups from 10 MeV to 10^{-3} eV. Harder spectrum can be achieved by either higher reload fuel enrichment (X) or a smaller hydrogen-to-heavy-metal (H/HM) ratio. Therefore, one can naturally give an asymptotic dependence of the epithermal-to-thermal flux ratio on the above two variables as.

$$\frac{\phi_2}{\phi_1} \approx \frac{H/HM}{X}$$

Explain the physical meaning of this equation.

(c) Repeat the k-inf, spectrum and epithermal-to-thermal flux ratio calculations for the same fuel cell but with Uranium nitride (UN) fuel. Assume 14.3 g/cm^3 density. Explain the differences in the results.

(d) For the UO_2 unit cell, modify the input file by adding a tally to obtain thermal, ϕ_2, and epithermal flux, ϕ_1, in the moderator. Calculate ratio of ϕ_2/ϕ_1 in the fuel and moderator. Discuss relative magnitude of the two and the reasons for differences.

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