22.351 Systems Analysis of the Nuclear Fuel Cycle
Fall 2005

Lab #4: MCNP PWR Pin Cell Model

A typical PWR unit cell MCNP model is given on the course web (file PIN.inp). 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/cm^3
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)

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

$$C^* = \frac{\text{U-238 captures}}{\text{U-235 fissions}},$$

$$\delta_{25} = \frac{\text{epithermal U-235 fissions}}{\text{thermal U-235 fissions}},$$

$$\rho_{28} = \frac{\text{epithermal U-238 captures}}{\text{thermal U-238 captures}}.$$

(b) Calculate and plot the neutron spectrum inside the fuel pellet, i.e., use a detailed energy structure as provided. Since it is straightforward to see that a harder spectrum can be achieved by either a higher reload fuel enrichment (*X*) or a smaller hydrogen-to-heavy-metal (H/HM) ratio, one can naturally give an asymptotic dependence of the epithermal-to-thermal flux ratio on the above two variables as

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

Explain the physical meaning of this equation.

(c) 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.