Preliminary Study for Few Group Constants Generation by a Whole Core Monte Carlo Calculation

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1. Introduction

In previous study, we proposed a Monte Carlo (MC) method augmented by the B_1 method and assessed the qualification of few group constants from the MC method in terms of the core depletion analysis for a PWR and VHTR system based on a two-step code system McCARD/MASTER[1,2,3]. In a PWR system, the critical spectrum by B_1 calculation predict very well with the actual spectrum. However, it is observed that neither infinite medium spectrum nor critical spectrum reflects accurately the spectra of the fuel blocks in a VHTR system. In this paper, we try to test the method to obtain the few group constants directly from whole core MC calculations.

2. Whole core MC group constants generation

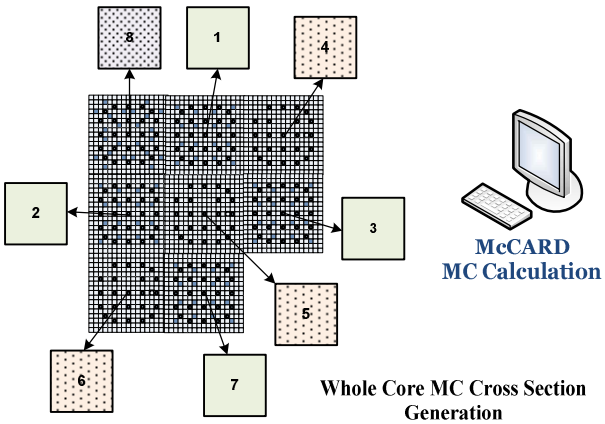

Fig. 1. Overview of Whole Core MC Cross Section Generation

MC method can handle the detailed geometric information and the continuous energy nuclear data. To take advantage of MC method, we generate the few group constants directly from a whole core MC calculation based on an exact modeling as shown in Fig. 1. On a whole core MC calculation, all the few group constants can be calculated by tallying group-wise reaction rates and neutron flux. The few group diffusion coefficients, D_G, are obtained by the condensation of the fine group diffusion coefficients calculated by the B_1 calculation for single fuel assembly with the real spectrum at a whole core calculation.

$$D_G = \frac{\sum_{g\in G} D_g \phi_g^{real}}{\sum_{g\in G} \phi_g^{real}} \quad (1)$$

The D_g and ϕ_g^{real} in Eq. (1) denote the diffusion coefficients, and neutron flux, of group g neutrons, respectively.

3. Numerical results

To examine the whole core MC cross section generation method, a PWR slab analysis was performed using the McCARD/MASTER code system. The reference solution was obtained from the direct McCARD. All the MC calculations are performed on the basis of 10,000 histories per a cycle with 1,000 active cycles and 50 inactive cycles. The 47-group structure of HELIOS is adopted for generation of the fine group constants for the B_1 calculations. To compare this method with the existing MC method augmented by the B_1 spectrum, the cross section generations by single fuel assembly calculations were performed additionally. Fig. 2 shows the configuration of the PWR slab consisting of three types of 17x17 PWR FA – D0, D1, and D2 FA. The width of slab is 216.07 cm while the height is 60cm.

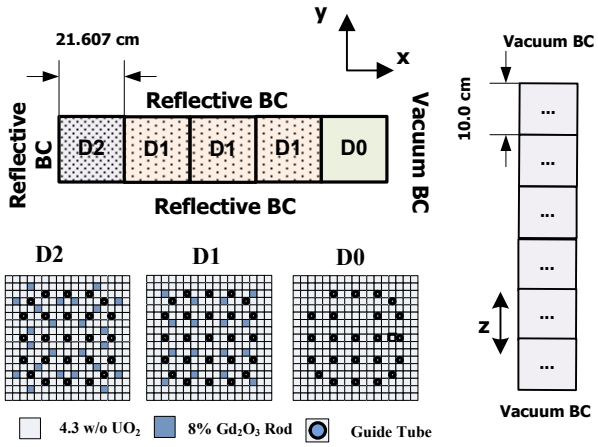

Fig. 2. Configuration of PWR Slab problem

Table I shows the k-effective of PWR slab problem for each case. The difference of k-effective between the whole core MC cross section generation method case and reference is only 6 pcm. Meanwhile, the difference

of k-effective with infinite-medium case is 243 pcm while that with the critical spectrum case is -320 pcm. Fig. 3 shows the assembly-wise power distributions. The RMS error of the power distribution by whole core MC method is 1.7%. The RMS error with the infinite-medium spectrum and critical spectrum is 4.1% and 1.9%, respectively.

Table I: k-effective for Slab Problem

Case	k-effective	Diff (pcm)
McCARD	1.00299 ±0.00029	-
McCARD/MASTER (Infinite-Medium Spectrum)	1.00542	243
McCARD/MASTER (Critical Spectrum)	0.99979	-320
McCARD/MASTER (Whole Core MC Generation)	1.00293	-6

D2	D1	D1	D1	D0
0.735	1.033	1.205	1.190	0.837
7.1	3.3	0.3	-2.2	-7.4
-1.9	-1.6	-1.1	1.1	3.6
-1.4	-1.3	-1.2	0.6	3.5

P_{Ref}	P_{Ref} = McCARD power	RMS Error
$Diff_{INF}$	$Diff_{INF}$ [%] = (P_{INF} - P_{Ref})/ P_{Ref}	INF^{*} = 4.1%
$Diff_{CRI}$	$Diff_{CRI}$ [%] = (P_{CRI} - P_{Ref})/ P_{Ref}	CRI^{**} = 1.9%
$Diff_{WC}$	$Diff_{WC}$ [%] = (P_{WC} - P_{Ref})/ P_{Ref}	WC^{***} = 1.7%

* INF = Infinite-Medium Spectrum case
** CRI = Critical Spectrum case
*** WC = Whole Core MC Generation method case

Fig. 3. Assembly-wise Power Distribution for Slab Problem

Fig. 4 compares the spectra of D0 fuel assembly in the fifth row with both infinite medium and critical spectrum at single assembly. In D0 fuel assembly case at boundary, it is observed that the spectra are far off critical and infinite medium spectrum around the fast energy region.

3. Conclusions

In this study, the McCARD/MASTER calculations with the few-group constants calculated by the whole core MC cross section generation method were performed and compared with the existing MC cross section generation method. The comparison between a whole core MC cross section generation method and reference for the k-effective and the power distributions shows a good agreement. We are currently studying the generation of the assembly discontinuity factor and diffusion coefficients on a whole core calculation.

REFERENCES

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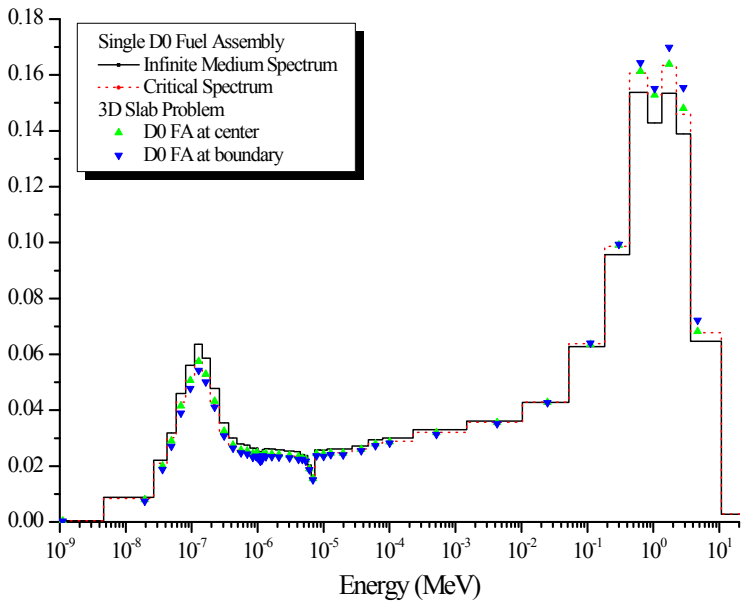

Fig. 4. Neutron Spectra for the fuel assembly of 3D Slab Problem