Qualification of McCARD/MASTER Code System for Yonggwang Unit 4

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1. Introduction

Recently, we have developed the new two-step procedure based on the Monte Carlo (MC) methods.[1] In this procedure, one can generate the few group constants including the few-group diffusion constants by the MC method augmented by the critical spectrum, which is provided by the solution to the homogeneous 0-dimensional B_1 equation. In order to examine the qualification of the few-group constants generated by MC method, we combine MASTER[2] with McCARD[3] to form McCARD/MASTER code system for two-step core neutronics calculations. In the fictitious PWR system problems, the core design parameters calculated by the two-step McCARD/MASTER analysis agree well with those from the direct MC calculations.

In this paper, a neutronic design analysis for the initial core of Yonggwang Nuclear Unit 4 (YGN4) [4] is conducted using McCARD/MASTER two-step procedure to examine the qualification of two group constants from McCARD in terms of a real PWR core problem. To compare with the results, the nuclear design report and measured data are chosen as the reference solutions.

2. The McCARD/MASTER Code system

Figure 1 shows the McCARD/MASTER code system. The assembly-homogenized few-group constants and form functions are generated by McCARD. The few-group constants are tabularized as a function of FA burnups, soluble boron concentration, fuel temperature, moderator temperature for MASTER calculations. MIG (McCARD Input Generator) utility code are used to perform the branch calculations, while the MOCHA (McCARD Output Convertor into HOPE Ascii table) is used to convert a output of McCARD into a cross section library set in PDQ format.

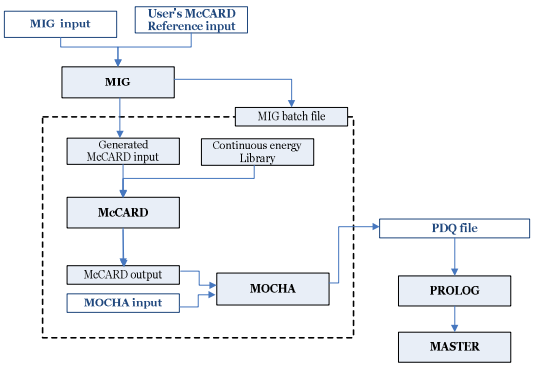

Fig. 1. Flow chart of McCARD/MASTER code system

3. Yonggwang Unit 4 Analysis

The initial YGN4 core consists of a total 177 FAs by nine difference types of FAs as shown in Fig. 2. In five FAs - types B1, B2, C1, D1, and D2, there are the shim rods, which consists of gadolinnia (Gd_2O_3) in the center and natural UO_2 in the top and bottom regions. Therefore, the two group constants are generated for the five cutback regions as well as the nine FAs as a function of the state parameters by McCARD on the basis of 200 active cycles with 10,000 histories per cycle at each depletion time step (DTS). Table 1 shows the state parameters for the branch calculations. The continuous energy cross sections are taken from ENDF/B-VI.8. The 47-group structure used in HELIOS[5] is adopted for generation of the fine group constants and the subsequent B_1 calculations.

The McCARD/MASTER calculations are performed with two sets of two-group constants from the infinite medium spectrum and the critical spectrum weighting.

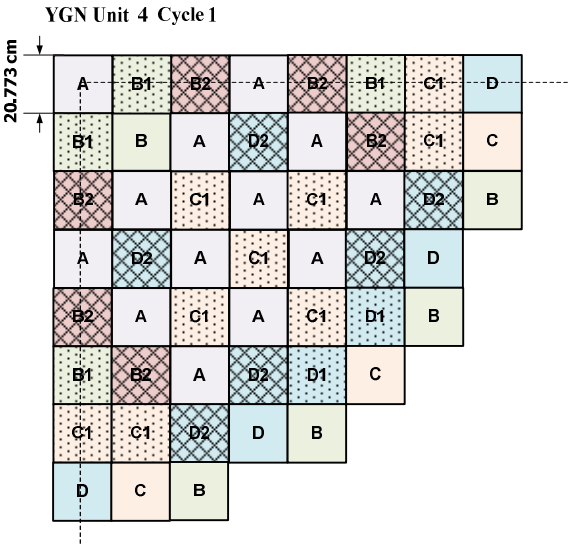

Fig. 2. Loading pattern of fuel assembly for YGN4 cycle1

Table I: Parameters for Branch Calculations

Parameter	Reference Calculation	Branch Calculation
Boron Concentration, ppm	500	1000
Fuel Temperature (K)	870	1273
Moderator Temperature(K)	585	563, 603
Moderator Density (g/cm^3)	0.70422	0.95000

3.1 Critical Boron Concentration

Figure 3 shows the critical boron concentration over the core burnup from 0 to 13.65 MWd/kgU. The circle points in red are the results by McCARD/MASTER while the black line is the NDR. For the purpose of comparison, the results by CASMO[6]/MASTER two-step calculations based on the deterministic transport codes are also included in Fig 3. With the NDR chosen as the reference, McCARD/MASTER results show the RMS error of 14.95 ppm while those of CASMO/MASTER calculations the RMS error of 30.79 ppm. Compared with the measure data, McCARD/MASTER results show the RMS error of 13.04 ppm while those of CASMO/MASTER calculations the RMS error of 28.59 ppm.

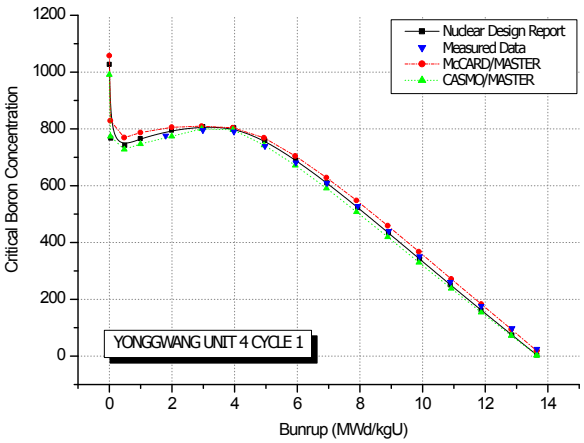

Fig. 4. Critical boron concentration of YGN4

3.2 Assembly-wise Power Distribution

Figure 5 show the reference NDR results, and the relative errors of McCARD/MASTER results for the normalized assembly-wise power distribution at 7.235MWd/kgU. The RMS error by the infinite-medium spectrum is 0.93% while that by the critical spectrum is 1.45%. The maximum error of the former is 2.4% while that of the latter is 5.2%. The results by the critical spectrum weighted few-group constants predict the assembly power distribution at critical states more than by the infinite-medium spectrum.

4. Conclusions

In this study, the two-step neutronic calculations for YGN4 are performed by McCARD/MASTER code system. The comparison between McCARD/MASTER and NDR for the critical boron concentration and the assembly-wise power distributions shows a good agreement. From these results, the few group constants generation module of McCARD was validated as a reliable few group constant generator.

Asm Type
NDR
Diff (INF)*
Diff (CRI)**

B	C	D
0.56	0.85	1
-5.2	-3.3	-3.6
0.0	-0.5	-0.7

B	D	D2	C1	C1
0.57	1.01	1.14	1.18	1.22
-4.9	-2.1	-0.2	0.0	0.2
0.7	1.2	0.5	-0.8	-0.8

C	D1	D2	A	B2	B1
0.68	1.11	1.26	0.87	1.22	1.07
-2.9	-0.7	0.6	1.8	0.6	0.9
2.4	0.6	0.5	-0.8	-1.0	-1.1

B	D1	C1	A	C1	A	B2
0.57	1.11	1.16	0.85	1.17	0.86	1.19
-4.9	-0.7	0.6	1.5	0.2	1.6	0.8
0.7	0.6	-0.1	-1.0	-0.8	-0.9	-0.4

D	D2	A	C1	A	D2	A
1.01	1.26	0.84	1.13	0.82	1.25	0.86
-2.1	0.6	1.5	0.4	1.4	0.8	1.8
1.2	0.5	-1.0	-0.2	-0.5	1.0	0.2

B	D2	A	C1	A	C1	A	B2
0.56	1.13	0.86	1.17	0.82	1.16	0.86	1.19
-5.2	-0.2	0.8	0.2	1.4	0.4	1.1	0.1
0.0	0.5	-1.9	-0.8	-0.5	0.7	0.2	0.6

C	C1	B2	A	D2	A	B	B1
0.85	1.18	1.22	0.86	1.26	0.86	1.21	1.02
-3.3	0.0	0.6	1.6	0.8	1.1	0.9	0.6
-0.5	-0.8	-1.0	-0.9	1.0	0.2	1.9	1.4

D	C1	B1	B2	A	B2	B1	A
1	1.22	1.07	1.19	0.86	1.19	1.02	0.83
-3.6	0.2	0.9	0.8	1.8	0.1	0.6	1.8
-0.7	-0.8	-1.1	-0.4	0.2	0.6	1.4	1.6

* Diff(INF) = (McCARD/MASTER(INF) - NDR)/ NDR * 100
** Diff(CRI) = (McCARD/MASTER(CRI) - NDR)/ NDR * 100

Fig. 5. Assembly-wise power distributions (13 EFPD)

Acknowledgement

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