Verification of the procedure to generate the homogenized multi-group cross section for VHTR fuel block using McCARD

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1. Introduction

McCARD/CAPP code system for designing Very High Temperature Gas Cooled Reactor (VHTR) core has been developed in the Korea Atomic Energy Research Institute (KAERI).

McCARD/CAPP code system carry out a neutronic analysis for VHTR through the generation of a homogenized cross section using McCARD (Monte Carlo Code for Advanced Reactor Design) [1] and the few group diffusion analysis using CAPP (Core Analyzer for Pebble and Prismatic type VHTRs) [2]. The previous procedure using HELIOS has the limits of not considering the axial heterogeneity [3] and the double heterogeneity which is the unique characteristics of VHTR fuel block. However, McCARD based on Monte Carlo Method has the function of handling the double heterogeneity. In addition, Seoul National University (SNU) recently implemented the module to generate the multi-group cross section table-sets into McCARD [4].

Thus, in this study, we carried out the verification calculations of the procedure to generate the homogenized multi-group cross section for VHTR fuel block using McCARD and investigated the feasibility of the McCARD/CAPP code system.

2. Generation of group cross sections

Figure 1 shows the whole procedure for neutronic analysis of VHTR core using McCARD/CAPP. In the left side of the figure, the procedure to generate few group cross sections is drawn, and we particularly performed the verification of the generation procedure in this paper.

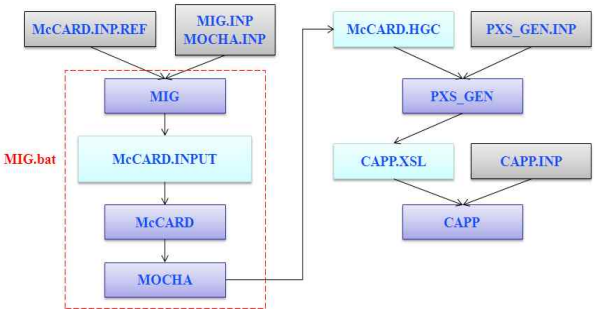

Fig. 1 Procedure of neutronic analysis using McCARD/CAPP code system.

2.1 Procedure to generate the cross sections

SNU developed the procedure to generate a homogenized multi-group cross section using McCARD and made the two assistant codes [4]. McCARD Input Generator (MIG) is the pre-processing code to automatically generate McCARD input considering temperature and burnup steps, and McCARD Output Convertor into Hope ASCII table (MOCHA) is the post-processing code to convert outputs of McCARD to cross section table-sets of ASCII type such as HGC format.

First step for the generation of the cross section table-sets is to execute MIG with an input of MIG and a reference input of McCARD. Then, only if executing MIG.bat generated by MIG, McCARD and MOCHA automatically run and finally the cross section sets with HGC format can be obtained. In this process, McCARD produces a flux spectrum and group constants with fine energy group and generates few group cross sections for the diffusion code using the spectrum. In this study, we used 190 groups for the fine energy group structure and 10 groups for the few energy group structure.

3. Results of Verifications

3.1 VHTR Fuel Block Model

For verifying the performance of the procedure described above, we carried out the analysis for single fuel block of PMR200 core as shown in Figure 2.

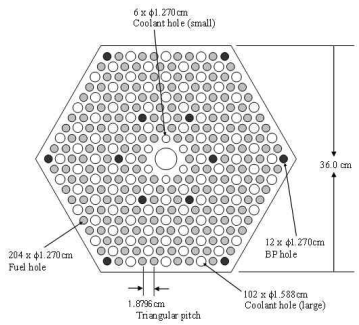

Fig. 2 C701 Fuel Block Configuration of PMR200

3.2 Comparison of Results

To examine the accuracy of the few group cross sections generated by McCARD, the comparisons between k_{inf} by McCARD and CAPP using the cross sections by McCARD are summarized in Table I and Figure 3. The column (A), (B), and (C) means the k_{inf} directly calculated by McCARD, the k_{inf} of the generated 10 group cross sections, and the k_{inf} calculated by CAPP using the cross sections, respectively.

The differences between the results by McCARD and by CAPP are less than about 120 pcm except second burnup step largely affected by burnup step size. For further investigation, the differences between (A), (B), and (C) are listed in the same table. The B-A errors including the stochastic error of McCARD calculation are about 100 pcm and are reasonably acceptable, because they are less than 3σ when considering the standard deviation of the calculation, about 40 pcm. The C-B errors are mainly ascribed to the difference of depletion chain and isotopes considered. Thus they are negligible at 0 day and increase to 40 pcm as the burnup goes.

From the comparisons, it can be inferred that the homogenized few group cross section table-sets are accurately generated by McCARD.

4. Conclusions

In this paper, to investigate the feasibility of the McCARD/CAPP code system, we carried out the verification calculations of the procedure to generate the homogenized few group cross sections for a single fuel block of PMR200 using McCARD and two assistant codes.

The differences between the results by McCARD and by CAPP are less than about 120 pcm including the stochastic error of McCARD calculation and they are reasonably acceptable when considering the standard deviation of the calculation.

Therefore, we concluded that the homogenized few group cross section table-sets generated by McCARD have sufficient accuracy and the McCARD/CAPP code system can be used for the core analyses of VHTR in the future.

REFERENCES

[1] H. J. Shim, et al., "McCARD: Monte Carlo Code for Advanced Reactor Design and Analysis," Nuclear Engineering and Technology, vol. 44, 161-176 (2012).
[2] H. C. Lee, et al., "Development of HELIOS/CAPP code system for the analysis of block type VHTR cores," Proceeding of PHYSOR 2012, Knoxville, Tennessee, USA, April 15-20, (2012).
[3] T. Y. Han, et al., "Homogenized Cross Section Generation Considering Axial Heterogeneity for VHTR Fuel Block," Proceedings of the HTR 2012, Tokyo, Japan, October 28–November 1, (2012).
[4] H. J. Park, et al., "Generation of Few Group Diffusion Theory Constants by Monte Carlo Code McCARD," Nucl. Sci. Eng., Accepted (2012).

Table I: k_{inf} of the C701 fuel block

Burnup (Days)	McCARD (k_{inf})		CAPP (C)	Error (pcm)		
	Real (A)	10G (B)		B-A	C-B	C-A
0	1.00248	1.00296	1.00295	48	-1	47
1	0.98952	0.99008	0.98682	56	-326	-270
4	0.98341	0.98371	0.98395	30	24	54
10	0.98723	0.98708	0.98730	-15	22	7
20	0.99277	0.99284	0.99297	7	13	20
40	1.00541	1.00525	1.00533	-16	8	-8
60	1.01830	1.01851	1.01851	21	0	21
90	1.03418	1.03422	1.03417	4	-5	-1
120	1.04690	1.04733	1.04732	43	-1	42
150	1.05727	1.05759	1.05765	32	6	38
180	1.06630	1.06725	1.06740	95	15	110
210	1.07367	1.07445	1.07466	78	21	99
240	1.07991	1.08079	1.08105	88	26	114
270	1.08490	1.08548	1.08577	58	29	87
300	1.08856	1.08924	1.08955	68	31	99
330	1.09158	1.09207	1.09239	49	32	81
360	1.09362	1.09329	1.09362	-33	33	0
390	1.09396	1.09433	1.09469	37	36	73
420	1.09373	1.09359	1.09397	-14	38	24
450	1.09287	1.09280	1.09314	-7	34	27
480	1.09146	1.09205	1.09240	59	35	94
510	1.08949	1.08897	1.08931	-52	34	-18
540	1.08644	1.08713	1.08743	69	30	99
570	1.08358	1.08398	1.08426	40	28	68
600	1.07989	1.08065	1.08088	76	23	99
630	1.07671	1.07620	1.07640	-51	20	-31
660	1.07145	1.07160	1.07177	15	17	32

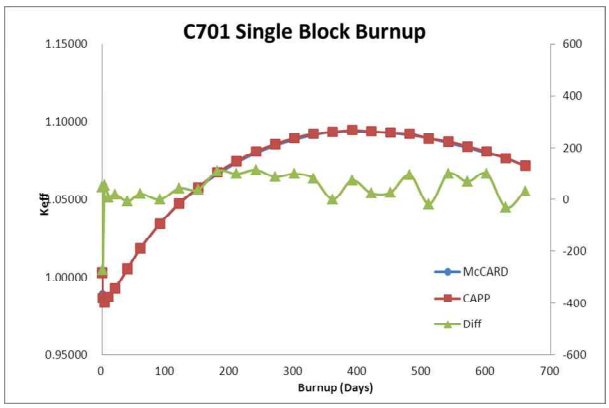

Fig. 3 k_{inf} of the C701 fuel block