McCARD Analysis for the OECD/NEA MHTGR-350 MW Benchmark

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1. Introduction

The OECD/NEA MHTGR-350 MW benchmark [1] based on the General Atomics Modular High Temperature Gas Reactor (MHTGR) is proposed to compare participants' analysis results. In this paper, we compare neutronic results calculated by McCARD [2] for Phase I Exercise 1 with a triangle-based polynomial expansion nodal (TPEN) diffusion code, RENUS (Reactor Numerical Simulator) and CAPP [3]. In the McCARD calculations, uncertainties of tallied means are estimated by the history-based batch method [4].

2. Benchmark Results

2.1 Phase I Exercise 1 of OECD/NEA MHTG-350 MW Benchmark

Phase I of the OECD/NEA MHTGR-350 MW benchmark is a steady-state problem and its exercise 1 is designed for a preliminary test of participant's neutronics code using given multi-group cross sections. The benchmark describes a 1/3 hexagonal reactor core shown in Fig. 1 and 26-group cross section sets for hexagonal assemblies. The simplified cross section set consists of Σ_{tg}, D_g, $\nu\Sigma_{fg}$, Σ_{fg}, χ_g, P_0 and P_1 scattering matrices. Figure 2 shows a cross section map of the 1/3 core with hexagonal and triangular models of a assembly with a control rod. In this study, we apply the hexagonal model for the control rod assembly.

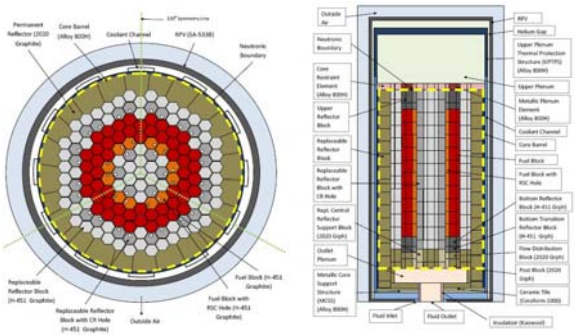

Fig 1. MHTGR-350 MW geometry.

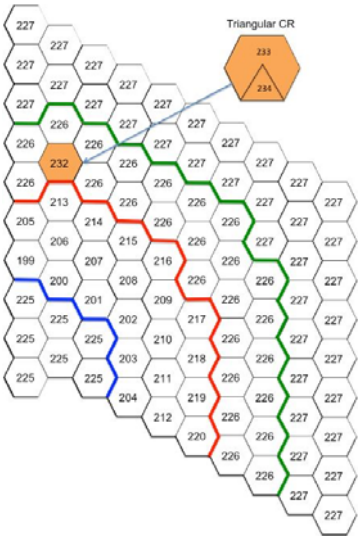

Fig 2. Cross section numbering of the 1/3 active core level 10

2.2 Fission Source Convergence Diagnosis in McCARD

The anterior stopping criteria [5] in McCARD are applied to obtain a number of inactive cycles ensuring the fission source convergence. The convergence is detected at the 53rd cycle by the stopping criteria. In this study, we apply 100 inactive cycles based on the diagnostic result.

McCARD calculations are performed with 200 active cycles on 1,000,000 histories per cycle and P_1 scattering matrices. RENUS and CAPP calculations are performed with P_0 scattering matrices. Table I compares k_{eff}'s calculated from McCARD, RENUS, and CAPP.

Table I: k_{eff} Results.

Model	Hexagonal CR		
Code	McCARD	RENUS	CAPP
k_{eff} (RSD)	1.06889 (0.00004)	1.06699	1.06720

3.2 Power Distribution and Its Real Variances

Figures 3 and 4 compares radial relative power distributions estimated by McCARD with those from RENUS and CAPP, respectively. RMS differences of the McCARD results with RENUS's and CAPP's are 1.4% and 1.5%, respectively.

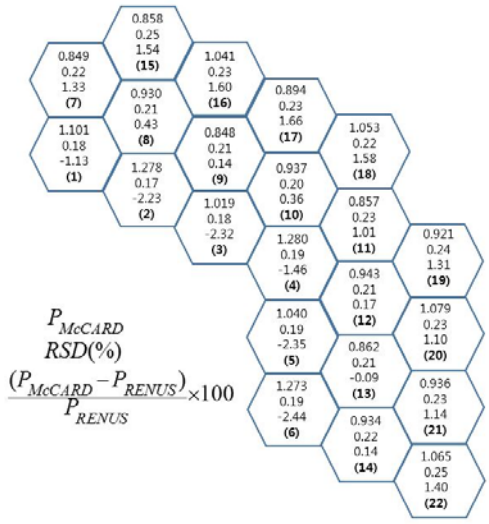

Fig 3. Comparison of radial relative power distribution of McCARD with RENUS results

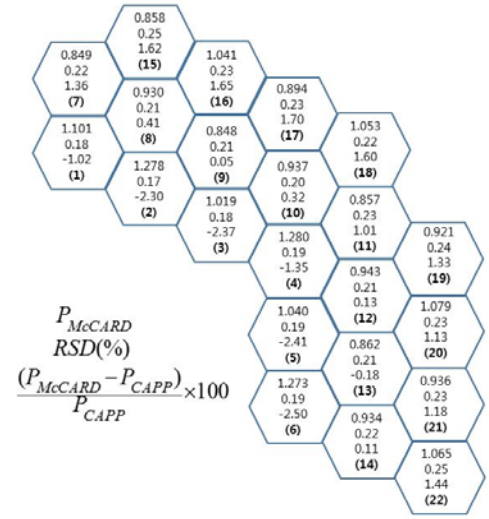

Fig 4. Comparison of radial relative power distribution of McCARD with CAPP results

Table II compares an axial relative power distribution calculated by McCARD with CAPP and RENUS results. RMS differences of the McCARD results with RENUS and CAPP are 1.3% and 1.4%, respectively.

Table II: Axial Relative Power Density Distribution of McCARD with CAPP and RENUS results.

Layer level	McCARD (RSD(%))	RENUS	CAPP
10	0.887 (0.56)	0864	0.872
9	1.134 (0.48)	1.131	1.136
8	1.272 (0.38)	1.279	1.283
7	1.286 (0.27)	1.298	1.300
6	1.239 (0.20)	1.251	1.251
5	1.080 (0.22)	1.091	1.087
4	0.973 (0.36)	0.979	0.975
3	0.857 (0.51)	0.857	0.853
2	0.704 (0.65)	0.698	0.693
1	0.567 (0.76)	0.553	0.549

In order to investigate the accuracy of the history-based batch method for the real variance estimation, we compare the estimated real variance with reference calculated from 100 repeated McCARD runs with changing the random seed. Table III show the comparisons of the estimated real standard deviation (SD), σ_{HB} and sample SD, σ_S with the reference, σ_{REF}.

Table III: Comparison of the Radial Fission Power Density Tallies RSDs (%).

Region	σ_{REF}	σ_{REF}/σ_S	σ_{REF}/σ_{HB}
1	0.163	3.6	0.9
2	0.149	3.4	0.9
3	0.163	3.5	0.9
4	0.179	4.1	1.0
5	0.149	3.2	0.8
6	0.140	3.2	0.7
7	0.192	3.8	0.9
8	0.182	3.8	0.9
9	0.192	4.0	0.9
10	0.201	4.3	1.0
11	0.213	4.3	0.9
12	0.184	3.9	0.9
13	0.168	3.5	0.8
14	0.164	3.5	0.8
15	0.200	3.8	1.2
16	0.208	4.2	0.9
17	0.232	4.5	1.0
18	0.229	4.5	1.0
19	0.225	4.3	0.9
20	0.208	4.2	0.9
21	0.187	3.7	0.8
22	0.186	3.6	0.7

4. Conclusions

McCARD analyses for the OECD/NEA MHTGR-350 MW benchmark are performed. k_{eff} calculated by McCARD agrees with CAPP and RENUS's within 200 pcm. And the relative power distribution results agree within RMS error of 1.5%.

REFERENCES

[1] "Prismatic Coupled Neutronics/Thermal Fluids Transient Benchmark of the MHTGR-350 MW Core Design – Benchmark Definition," Draft date : 07/16/2013.
[2] H. J. Shim, et al., McCARD: Monte Carlo Code for Advanced Reactor Design and Analysis, *Nucl. Eng. Technol.*, 44[2], 161~176, 2012.
[3] H. C. Lee, et al., Development of HELIOS/CAPP Code System for the Analysis of Block Type VHTR Cores, PHYSOR 2012, Knoxville, Tennessee, USA, April 15-20, 2012.
[4] H. J. Shim, S. H. Choi, C. H. Kim, Real Variance Estimation by Grouping Histories in Monte Carlo Eigenvalue Calculations, *Nucl. Sci. Eng.*, 176, 58-68, 2014.
[5] H. J. Shim and C. H. Kim, Stopping Criteria of Inactive Cycle Monte Carlo Calculations, *Nucl. Sci. Eng.*, 157, 132-141, 2007.