

From ENDF/B-VII.1 to ENDF/B-VIII.1: Preliminary Application of Correction-Factor Method for Easy Nuclear Data Library Generation

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1. Introduction

As part of recent global initiatives toward carbon neutrality, various Small Modular Reactors (SMRs) and next-generation reactors has been widely developed. In general, the accuracy of the new nuclear reactor core design parameters (i.e., reactivity, power distribution, and shutdown margin) is highly dependent on the precision of nuclear cross section library. Accordingly, various evaluated nuclear data libraries (ENDL) have been developed and updated in many countries through experimental measurements.

Recently, Kyung Hee University (KHU) has studied the methodology for applying correction factors [1-2] to enhance the accuracy of multi-group nuclear data library. Following this methodology, correction factors are derived from the ratios of group-wise reaction rates calculated by the DeCART2D [3] lattice code to those obtained from reference Monte Carlo (MC) solutions. The McCARD code was utilized as a reference MC code [4] providing the reaction rates across various energy groups, nuclides, and temperatures for the determination of individual correction factors.

In this study, motivated by the convenience of generating correction factors, we aim to produce a new version of a nuclear data library by applying correction factors to an older library. Using MC solutions based on ENDF/B-VIII.1, the widely used ENDF/B-VII.1 DeCART2D lattice code library is converted into a ENDF/B-VIII.1 library [5].

2. Brief Explanation for Library Correction Procedure in DeCART2D Library Generation

In this study, we applied the correction factor method proposed in the previous study [1-2] to improve the accuracy of the multi-group (MG) cross-section library for DeCART2D. The correction factor method compensates for the discrepancy between the MC reference and the deterministic transport results arising from spectral approximation. The correction factor can be calculated as the ratio of reaction rates obtained from the deterministic code and the MC reference code, and it is individually considered as a function of nuclide, energy group, and temperature. In previous studies, the correction factor method has been applied to improve the multigroup (MG) library of the lattice analysis code

DeCART2D developed by Korea Atomic Energy Research Institute (KAERI). In this case, the reference solutions were calculated by the MC code McCARD. A detailed description of the application of the correction factor can be found in previous studies [1].

This study proposes the use of the correction factor method to upgrade the existing old library into a new, improved version. In this case, the initial stage of generating correction factors begins with the old DeCART2D MG library, while the reference solutions are calculated by McCARD with the target version of the new nuclear cross section library. Thus, by applying the correction factors, the initial MG cross sections can be adjusted and converged to be consistent with the new cross section.

This study produced an ENDF/B-VIII.1 DeCART2D library by applying correction factors to the ENDF/B-VII.1 version, using reference solutions generated by McCARD based on the ENDF/B-VIII.1 data. The corrected library was generated with 4 iterations of correction. Figure 1 shows the overall process. Here, x , g , and T respectively denote the type of nuclear reaction, energy group, and temperature point of the nuclide. In addition, De refers to DeCART2D, and MC refers to McCARD. $\sigma_{x,g}^{MC}$ and $\sigma_{x,g}^{De,(n)}$ denote the groupwise cross section from McCARD and DeCART2D respectively, and ϕ_g represents the corresponding neutron flux.

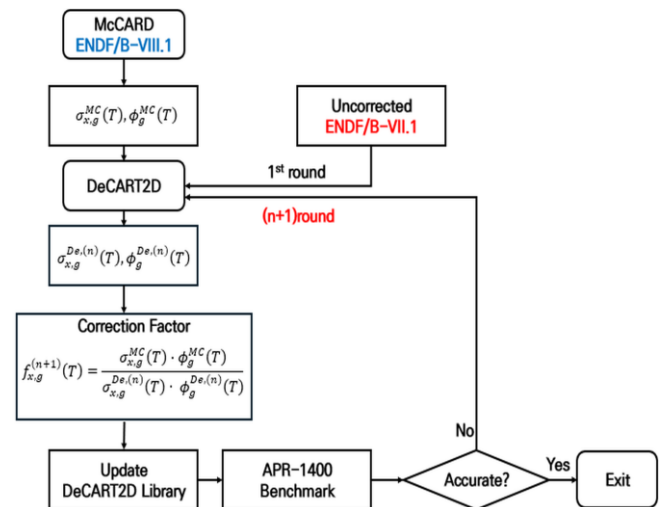


Fig. 1. Flowchart of DeCART2D library correction process

McCARD simulations were carried out for a reference model set to the APR-1400 B3 assembly with a boron concentration of 1000 ppm, and the group- and nuclide-specific cross sections for absorption, fission, and scattering from DeCART2D were adjusted to match those from McCARD.[4] The considered nuclides were ^{235}U , ^{238}U , ^1H , ^{10}B , ^{154}Gd , ^{155}Gd , ^{156}Gd , ^{157}Gd , ^{158}Gd , and ^{160}Gd . After correction, the adjusted library was applied to the APR-1400 benchmark problem. The resulting simulation outputs were compared with those obtained from the McCARD with ENDF/B-VIII.1 about APR-1400 benchmark problem.

3. Conversion of ENDF/B-VII.1 to ENDF/B-VIII.1 and APR-1400 Benchmark Analysis

The APR-1400 benchmark specifies detailed core geometry and material compositions. The reactor core adopts a 17×17 lattice configuration consisting of 241 fuel assemblies (FAs), each with 236 fuel rods. Among the APR-1400 benchmark problems, the single pin cell problem and the 2D FA problem consist of 45 and 81 problems, respectively. Table I summarizes the sub-problems defined in the benchmark.

Table I: Summary of APR-1400 Benchmark

No.	Problem Type	Conditions Summary
1	Single Fuel Pin	5 enrichments, 3 temperature points 3 boron levels
2	2D Assembly	9 assemblies, 3 temperature points, 3 boron levels

3.1 Single Pin Cell Problem

APR-1400 fuel rods have enrichment levels of 1.71, 2.00, 2.64, 3.14, and 3.64 w/o with different types of operating condition and boron concentration. Table II lists the corresponding problem IDs. Problem IDs are assigned by combining the operating condition Cold Zero Power, Hot Zero Power, or Hot Full Power with the boron concentration level: '0' for 0 ppm, '1' for 1000 ppm, and '2' for 2000 ppm.

Table II: Temperature and Boron Concentration Settings for APR-1400 Benchmark

No.	Problem ID	Fuel Temp (K)	Clad Temp (K)	Moderator Temp(K)	Boron (ppm)
1	CZP0	300	300	300	0
2	HZP0	600	600	600	0
3	HFP0	900	600	600	0
4	CZP1	300	300	300	1000
5	HZP1	600	600	600	1000
6	HFP1	900	600	600	1000
7	CZP2	300	300	300	2000
8	HZP2	600	600	600	2000
9	HFP2	900	600	600	2000

For the single pin cell problem, RMS error of the reactivity difference between the McCARD reference

solutions and the DeCART2D calculation results using the corrected library is 104 pcm. In addition, when the uncorrected library is used, the RMS error in reactivity difference is 512 pcm. Figure 2 shows the results of the single pin problem for each Problem ID.

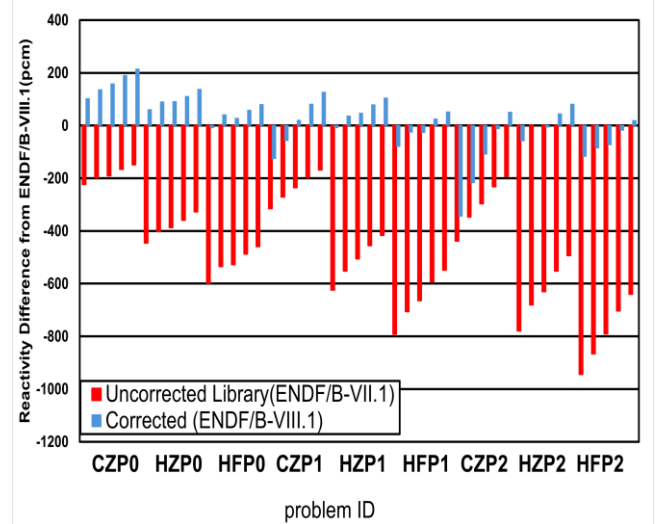


Fig. 2. Reactivity errors for the APR-1400 single pin cell problems

3.2 2D Fuel Assembly Problem

For the 2D FA problems, RMS error of the reactivity difference between solutions and DeCART2D using corrected library is 150 pcm. When uncorrected library is used, the RMS error of reactivity difference is 660 pcm. Figure 3 shows the results of the 2D FA problem for each Problem ID. The Problem ID is based on enrichment and the presence of gadolinium (Gd) burnable absorbers, nine FA types are defined: A0, B0–B3, and C0–C3.

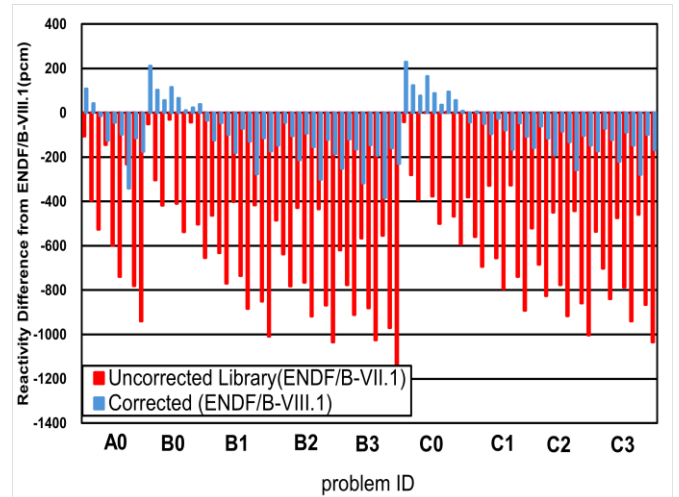


Fig. 3. Reactivity errors for the APR-1400 2D FA problems

4. Conclusion

In this study, a simple and straightforward approach was introduced to update the existing lattice code MG library into a new version by applying the correction factor method. For verification, the ENDF/B-VII.1 DeCART2D library was converted into a simplified ENDF/B-VIII.1 library using the correction factors by McCARD with ENDF/B-VIII.1 library, and the APR-1400 benchmark was subsequently analyzed. In the single pin cell and 2D FA problems, the RMS errors of the reactivity differences were 104 pcm and 150 pcm, respectively. The observed reduction in error was smaller than expected, likely resulting from differences in nuclide-specific reaction rates and neutron spectral characteristics introduced by updates to the evaluated nuclear data library.

Future work will focus on developing methods to achieve stable convergence of the differences. Based on these preliminary analysis results, the newly-introduced approach will be improved to apply in actual nuclear core design analyses as a practical way.

Acknowledgment

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REFERENCES

- [1] C. Kim and H. J. Park, "Improvement of DeCART2D multigroup cross section library correction system and APR-1400 benchmarking," *Nucl. Eng. Technol.*, 57, 103820, 2025.
- [2] H. J. Park et al., "An improved DeCART library generation procedure with explicit resonance interference using continuous energy Monte Carlo calculation," *Ann. Nucl. Eng.*, 105, pp. 95–105, 2017.
- [3] J. Y. Cho et al., "DeCART2D v1.1 User's Manual," KAERI/UM-40/2016, 2016.
- [4] H. J. Shim et al., "McCARD: Monte Carlo Code for Advanced Reactor Design and Analysis," *Nucl. Eng. Technol.*, 44, pp.151-176, 2012.
- [5] S. Yuk, "APR1400 Reactor Core Benchmark Problem Book," Technical Report RPL-INERI-CA-004, KAERI, Daejeon, South Korea, 2019.