Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Comparison of Uncertainty for HTGR UAM Benchmark Based on Covariance Data of ENDF/B-VII.1 and ENDF/B-VIII.0

Tae Young Han*, Chang Keun Jo
Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, Korea
**Corresponding author: tyhan@kaeri.re.kr*

1. Introduction

Uncertainty for a neutronic parameter can be quantified by combining the sensitivity for the core parameter and the covariance data given in the evaluated nuclear data library. In the uncertainty analysis, it is well known that the covariance data has the greatest effect on the uncertainty.

Recently, ENDF/B-VIII.0 was released and the covariance data was newly updated. The new version introduced great changes in the neutron libraries and their covariance data. In particular, it is found that there are large discrepancies in the covariance for ^{235}U and ^{238}U, compared with ENDF/B-VII.1 covariance data.

Thus, this paper presents the comparisons of the uncertainty for HTGR problem based on the two covariance data originated from ENDF/B-VII.1 and ENDF/B-VIII.0. For the investigation, the HTGR UAM benchmark problems [1] were used and our uncertainty analysis code system, DeCART/MUSAD, was applied.

2. Code System

For an uncertainty analysis of a high temperature gas-cooled reactor (HTGR), the MUSAD (Modules of Uncertainty and Sensitivity Analysis for DeCART) [2] code has been developed based on the generalized perturbation theory for the last few years. The code is used in the lattice physics analysis step of the two-step uncertainty analysis procedure. It can provide sensitivities and uncertainties for general responses with the generalized adjoint fluxes calculated by the DeCART code [3] and generates randomly sampled few-group cross section sets for a core simulation code.

The DeCART code can directly solve the generalized adjoint equation for the double heterogeneity (DH) region which is composed of the graphite matrix and TRISO fuel particles randomly dispersed in the matrix.

In addition, ERRORR module of NJOY2016 [4] was applied to generate the covariance matrix with the 190 group structure from the evaluated nuclear data files.

3. HTGR UAM Benchmark

MHTGR-350 Ex. I-1a and Ex. I-1b benchmarks provided by IAEA HTGR UAM CRP [1] consist of the UCO fuel compact, a small gap, and the surrounding block graphite. Ex. I-1a specifies a homogeneous fuel compact of smeared-out TRISO fuel particles and matrix graphite. Ex. I-1b, however, has a DH fuel compact which contains explicit UCO TRISO particles randomly dispersed in the graphite matrix. Figure 1 and 2 show the geometrical configuration of Ex. I-1a and b, respectively.

The Ex. I-2a problem is composed of 210 fresh fuel pins defined in Ex. I-1b and 6 lumped burnable poisons in the six corners of the block shown in Figure 3.

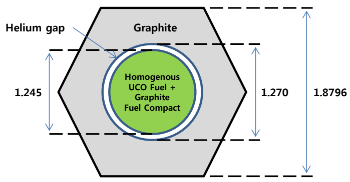

Fig. 1. Configuration for Ex. I-1a

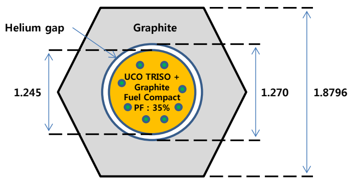

Fig. 2. Configuration for Ex. I-1b

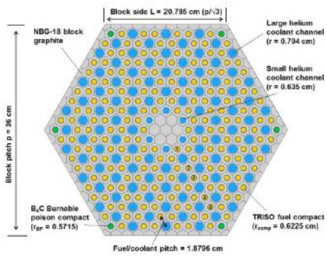

Fig. 3. Configuration for Ex. I-2a

4. Comparison of Covariance Matrix

Figure 4 and 5 show the plot of the covariance matrix with 190 group structure for ^{235}U ν from ENDF/B-VII.1 and ENDF/B-VIII.0. The left top side is thermal energy region and the right bottom side is fast energy region.

They present that there are considerable discrepancies in the intermediate energy groups. In the ENDF/B-VIII.0, the values of the diagonal elements are larger and those of the off-diagonal elements are smaller. It means that a variance of ^{235}U ν for an energy group is large and covariances with other groups are small.

In addition, figure 6 and 7 show the covariance matrix for the ^{238}U capture cross section from two libraries. It reveals that there are slight differences in the fast energy groups. Even though the difference is small, the impact to the k_{eff} uncertainty can be significant, because the ^{238}U capture cross section is one of the largest contributor to the total uncertainty.

5. Comparison of Uncertainty

The uncertainties for MHTGR-350 Ex. I-1a, 1b, and 2a were quantified using DeCART/MUSAD code system with the covariance data based on ENDF/B-VII.1 and ENDF/B-VIII.0. The code used the cross section library based on ENDF/B-VII.1. Because the covariance data is relative value, the effect by the different version between the covariance data and the cross section library is very small.

Table I shows the k_{inf} uncertainty for Ex. I-1a based on the two covariance data. It reveals that there are huge differences in the first and second contributor, ^{235}U ν and ^{238}U capture cross section. In the case of ^{235}U ν- ν, the contribution is lower by 26%. In the case of ^{238}U capture-capture cross section, the contribution is lower by about 50%. Thus, the total k_{inf} uncertainty decreases from 915 pcm to 612 pcm in the Ex. I-1a HFP problem. It means that the cross section uncertainty is smaller in the new nuclear data library and k_{inf} uncertainty induced from the cross section uncertainty considerably decreases. However, it shows that the uncertainty contribution by the C scattering cross section is larger and it needs to pay attention to that in the HTGR problem.

Table II and III show the k_{inf} uncertainty for Ex. I-1b and Ex. I-2a, respectively. They also show that the trends in the change of the uncertainty are similar to the Ex. I-1a problem. In particular, the contribution by ^{235}U fission-fission cross section is slightly larger by 20% due to the large graphite moderator in the block, comparing with the pin cell problem.

6. Conclusions

In this paper, the comparisons of the uncertainty based on the two covariance data from ENDF/B-VII.1 and ENDF/B-VIII.0 were presented. The uncertainty analysis for the HTGR UAM benchmark problems was performed using the DeCART/MUSAD code system.

The calculation results reveal that there are significant differences in the first and second contributor, ^{235}U ν and ^{238}U capture. Thus, the total k_{inf} uncertainty is lower by 30% in the HTGR benchmark problem.

From the results, it is expected that the new covariance data can improve the reliability of the neutronic parameter uncertainty analysis.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No.2017M2A8A1014757).

REFERENCES

[1] Strydom. G., et al., IAEA Coordinated Research Project on HTGR Reactor Physics, Thermal-hydraulics and Depletion Uncertainty Analysis: Prismatic HTGR benchmark Definition: Phase I, INL/EXT-15-34868, Revision 1, August, (2015).

[2] Han. T. Y., et al., "Development of a sensitivity and uncertainty analysis code for high temperature gas-cooled reactor physics based on the generalized perturbation theory," Annals of Nuclear Energy, 85, 501-511, (2015).

[3] Cho. J. Y., et al., "Whole core transport calculation employing hexagonal modular ray tracing and CMFD formulation," J. Nucl. Sci. Technol. 45, 740–751, (2008).

[4] MacFarlane. R. E., et al., The NJOY Nuclear Data Processing System, Version 2016, LA-UR-17-20093, Los Alamos National Laboratory, (2018).

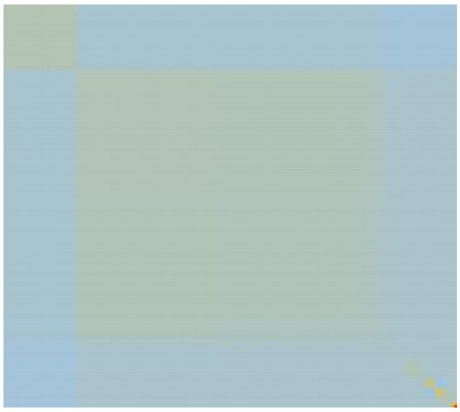

Fig. 4. Covariance matrix for ^{235}U ν of ENDF/B-VII.1

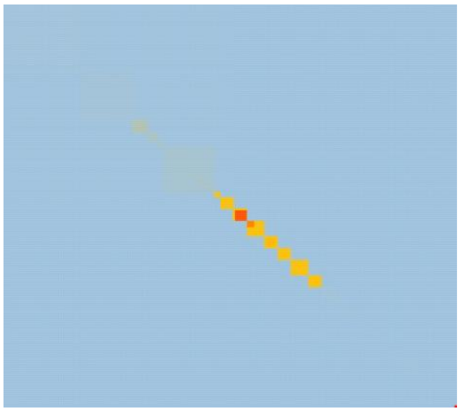

Fig. 5. Covariance matrix for ^{235}U ν of ENDF/B-VIII.0

Fig. 6. Covariance matrix for ^{238}U capture of ENDF/B-VII.1

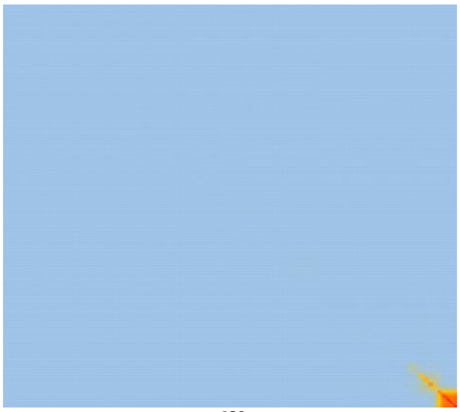

Fig. 7. Covariance matrix for ^{238}U capture of ENDF/B-VIII.0

Table I: Uncertainty for Ex.I-1a

Contributor	Ex. I-1a CZP (*Δk/k* (%))		Ex. I-1a HFP (*Δk/k* (%))	
	DeCART /MUSAD		DeCART /MUSAD	
	Cov.71	Cov.80	Cov.71	Cov.80
^{235}U ν-ν	0.616	0.453	0.610	0.453
^{235}U cap-cap	0.239	0.081	0.236	0.092
^{235}U fis-cap	0.072	0.037	0.074	0.038
^{235}U fis-fis	0.066	0.074	0.073	0.078
^{238}U ν-ν	0.008	0.008	0.009	0.009
^{238}U cap-cap	0.480	0.271	0.606	0.318
^{238}U fis-fis	0.002	0.004	0.002	0.002
C scat-scat	0.146	0.200	0.162	0.222
C scat-cap	0.003	0.003	0.003	0.003
C cap-cap	0.023	0.023	0.023	0.023
Total	0.838	0.579	0.915	0.612

Table II: Uncertainty for Ex.I-1b

Contributor	Ex. I-1b CZP (*Δk/k* (%))		Ex. I-1b HFP (*Δk/k* (%))	
	DeCART /MUSAD		DeCART /MUSAD	
	Cov.71	Cov.80	Cov.71	Cov.80
^{235}U ν-ν	0.617	0.453	0.612	0.453
^{235}U cap-cap	0.240	0.082	0.238	0.093
^{235}U fis-cap	0.071	0.037	0.073	0.037
^{235}U fis-fis	0.065	0.074	0.071	0.078
^{238}U ν-ν	0.008	0.008	0.008	0.009
^{238}U cap-cap	0.444	0.256	0.562	0.305
^{238}U fis-fis	0.002	0.002	0.002	0.002
C scat-scat	0.140	0.192	0.158	0.216
C scat-cap	0.003	0.003	0.003	0.003
C cap-cap	0.024	0.024	0.023	0.023
Total	0.805	0.569	0.888	0.602

Table III: Uncertainty for Ex.I-2a

Contributor	Ex. I-2a HFP (*Δk/k* (%))	
	DeCART /MUSAD	
	Cov.71	Cov.80
^{235}U ν-ν	0.620	0.452
^{235}U cap-cap	0.184	0.073
^{235}U fis-cap	0.086	0.036
^{235}U fis-fis	0.117	0.141
^{238}U ν-ν	0.007	0.007
^{238}U cap-cap	0.421	0.233
^{238}U fis-fis	0.002	0.004
C scat-scat	0.141	0.194
C scat-cap	0.003	0.003
C cap-cap	0.027	0.027
Total	0.803	0.570