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Uncertainty Analysis of k_{eff} on the GODIVA Core Using Recently Developed Covariance Data

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1. Introduction

The uncertainties of calculated integral nuclear parameters such as k_{eff} values, reaction rates, reactivity worths, spent fuel isotopic concentrations, etc., are most likely caused by the inevitable approximations in cross-section data, description of the geometry, and material compositions. The uncertainties in the integral parameters due to cross sections can be assessed using cross-section covariance data produced directly from the uncertainties of the measurements. Uncertainty assessments with covariance data have been continually used in reactor physics relating to the safety margin predictions and/or optimized integral benchmark facility designs for the next nuclear systems. [1]

2. Calculations and Results

The sensitivity and uncertainty analyses of k_{eff} on the GODIVA [2] core with recent Oak Ridge National Laboratory (ORNL) evaluations and JENDL-3.3 were carried out. The GODIVA benchmark is an experiment for a fast reactor fueled with 94 wt % enriched ^{235}U. The ORNL evaluations of ^{235}U covariance data were performed using the retroactive methods implemented in the SAMMY code for the resolved resonance energy region.

The covariance data were processed with PUFF-IV and ERRORJ codes, and the processed coverx-format data were very similar. The analyses of sensitivity and uncertainty were carried out with TSUNAMI and SUSD3D codes. [3-6] The eigenvalue and associated uncertainty for the GODIVA core were calculated with KENO-V.a/TSUNAMI using the 238 energy group cross-sections of ENDF/B-VI and JENDL-3.3, and covariance data of the ORNL evaluation and JENDL-3.3. For comparison, the eigenvalue and uncertainty were also calculated with ANISN/SUSD3D using the 44 energy group nuclear data of JENDL-3.3.

Table 1 shows calculated k_{eff} values and uncertainties with various combinations of cross-section and covariance data for the GODIVA benchmark. The sensitivity and uncertainty were calculated using the new ORNL-generated covariance data and the JENDL-3.3 covariance data for ^{235}U. The sensitivity and uncertainty of inelastic reaction are calculated using nonelastic data (MT 4) in TSUNAMI code. However, the sensitivity/uncertainty calculations of inelastic scattering with JENDL-3.3 should be carried out using the individual inelastic data. The uncertainties in Table 1 were also presented excluding the uncertainties due to the inelastic reactions of ^{235}U for comparison.

3. Discussions and Conclusions

The uncertainties using the ENDF/B-VI and JENDL-3.3 cross-section data do not show large difference (A and C, B and D in Table 1). The differences in sensitivities to k_{eff} values by different cross section data are not large. The differences in uncertainties are mainly caused by the covariance data (A and B, C and D in Table 1). The uncertainty with the ORNL-generated covariance data is about two times larger than with JENDL-3.3. The differences in the uncertainties mainly come from the uncertainties of (n,gamma) reactions and ν–bar. The results of KENO-V.a/TSUNAMI and ANISN/SUSD3D show a very good agreement although different spectra and energy groups were used.

The uncertainty of k_{eff} on the fast benchmark GODIVA was calculated using the recent covariance data. The calculated uncertainties of k_{eff} on the GODIVA core are 1.01% with the ORNL ^{235}U evaluation and 0.58% with the JENDL-3.3 covariance data. The results of TSUNAMI and SUSD3D show very good agreements.

REFERENCES

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[2] International *Handbook of Evaluated Criticality Safety Benchmark Experiments*, NEA/NSC/DOC(95)03, OECD Nuclear Energy.
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[5] B.T. Rearden, TSUNAMI-3D: *Control Module for Three-Dimensional Cross-Section Sensitivity and Uncertainty Analysis for Criticality*, ORNL/TM-2005/39, Version 5.1, Vol. I, Book 2, Sect. C9, (November 2006).
[6] SUSD3D: A Multi-Dimensional, Discrete-Ordinates Based Cross Section Sensitivity and Uncertainty Analysis Code System, RSICC Code Package: CCC-695 (2000).

Table 1. Comparisons of k_{eff} and uncertainties calculated with the different cross-section and covariance data of ^{235}U in the GODIVA benchmark

Calculation codes	Spectrum/ Eigenvalue	SCALE/ KENO-V.a						ANISN	
	Sensitivity/ Uncertainty	TSUNAMI						SUSD3D	
Cross-section library		ENDF/B-VI			JENDL-3.3			JENDL-3.3	
Energy groups		238			238			44	
Value for k_{eff} (standard dev.)		0.99735 (0.00024)			1.00322 (0.00022)			1.01108	
Covariance data		ORNL (A)	JENDL (B)	Ratio (B/A)	ORNL (C)	JENDL (D)	Ratio (D/C)	JENDL (E)	Ratio[c] (E/D)
Uncertainty due to ^{235}U (%)	Total [a]	1.05 (1.01)[b]	0.46	0.44	1.15 (1.16)[b]	0.43	0.37	0.43 (0.58)[b]	1.00
	(n,g) (n,g)	0.71	0.14	0.20	0.86	0.15	0.18	0.17	1.10
	ν-bar	0.54	0.15	0.28	0.54	0.15	0.27	0.15	1.01
	(n,n) (n,n)	0.36	0.37	1.03	0.33	0.33	1.01	0.32	0.96
	(n,n) (n,g)	0.31	0.07	0.22	0.35	0.07	0.21	0.05	0.67
	(n,f) (n,f)	0.27	0.17	0.62	0.27	0.17	0.62	0.17	1.00
	(n,n) (n,f)	-0.08	-0.05	0.64	-0.08	-0.05	0.66	-0.03	0.66
	(n,2n) (n,2n)	0.01	0.01	0.54	0.02	0.01	0.56	0.01	0.92
	(n,n) (n,2n)	-0.01	-0.00	0.66	-0.01	-0.00	0.66	-0.00	0.57

[a] : not include the uncertainties of inelastic reaction.
[b] : includes the uncertainty of inelastic reaction
[c] : (ANISN/SUSD3D) / (KENO-V.a/TSUNAMI)