A Sensitivity and Uncertainty Analysis of k_{eff} Values on Fast and Thermal Benchmarks with the Covariance Data

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The uncertainties of calculated integral nuclear parameters such as k_{eff} values, reaction rates, reactivity worths, spent fuel isotopic concentrations, etc., must be 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 measurements. The uncertainty assessments with the 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] The present study includes (1) assessments and analyses of uncertainties in k_{eff} with available covariance data and analysis tools and (2) identification of the need for and potential benefits of new covariance data evaluations for reduction of the uncertainties. In addition, covariance data processing codes and sensitivity analysis codes are compared.

Analyses of Sensitivity/Uncertainty on Fast and Thermal Benchmarks

The sensitivity and uncertainty analyses of k_{eff} on the fast and thermal cores with recent Oak Ridge National Laboratory (ORNL) evaluations and JENDL-3.3, as well as with ENDF/B-VI data, were carried out. The ORNL evaluations of ^{235}U and ^{239}Pu 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, and analyses of sensitivity and uncertainty were carried out with TSUNAMI and SUSD3D codes.[3-6] GODIVA (^{235}U) and JEZEBEL (^{239}Pu) cores for fast benchmarks and HEU-SOL-THERM-013 (^{235}U) and PNL-1 (^{239}Pu) cores for thermal benchmarks[7] were selected for this study. The eigenvalues and associated uncertainties for four benchmarks were calculated with KENO-V.a, TSUNAMI, and ENDF/B-VI-based nuclear data and covariance libraries.[8] Table 1 shows calculated k_{eff} values and uncertainties. The calculated uncertainties due to cross sections are very large compared with experimental uncertainties, especially for the fast cores. The sensitivities and uncertainties were calculated using the original ENDF/B-VI covariance data, the new ORNL-generated covariance data, and the JENDL-3.3 covariance data for ^{235}U and ^{239}Pu. Total uncertainties for the benchmark cores are caused primarily by those for each of the fissile isotopes. Significant reductions in the uncertainties are expected with the ORNL evaluations and JENDL-3.3 (Table 1). For the thermal core presented here, HEU-SOL-THERM-013, the uncertainties in k_{eff} due to the ORNL and ENDF/B-VI covariance data for ^{235}U are very close. The calculated integral sensitivities for the benchmarks are shown in Fig. 1. The k_{eff} values are the most sensitive to ν-bar. The k_{eff} is also very sensitive to the scattering and capture cross sections of hydrogen for thermal cores.

		Fast Benchmarks		Thermal Benchmarks	
		HEU-MET-FAST-001 (GODIVA)	PU-MET-FAST-001 (^{239}Pu-JEZEBEL)	HEU-SOL-THERM-013	PU-SOL-THERM-021 (PNL-1)
Fissile (Enrichment)		^{235}U (94 wt. %)	^{239}Pu (95.2 atom %)	^{235}U (93.2 wt. %)	^{239}Pu (95.1 atom %)
Radius (Sphere)		8.7407 cm	6.38493 cm	34.5948 cm	19.5085 cm
EALF (eV)		9.477×10^{5}	1.240×10^{5}	3.231×10^{-2}	6.594×10^{-2}
Value for k_{eff} (standard dev.)	Exp.	1.000 (0.001)	1.000 (0.002)	1.0012 (0.0026)	1.0000 (0.0032)
	Calc.	0.99735 (0.00024)	0.9953 (0.00024)	0.99976 (0.00019)	1.01268 (0.0003)
Total uncertainty (ENDF/B-VI)		1.612%	2.439%	0.825%	1.340%
Primary fissile nuclide		^{235}U	^{239}Pu	^{235}U	^{239}Pu
ENDF/B-VI covariance data (*dk/k*) due to the primary fissile isotope		1.608%	2.381%	0.730%	1.225%
ORNL covariance data (*dk/k*) due to the primary fissile isotope		1.018%	0.641%	0.744%	0.629%
JENDL-3.3 covariance data (*dk/k*) due to the primary fissile isotope		-	0.452%	0.308%	0.085%

Table 1. Comparisons of k_{eff} and uncertainties calculated with the different covariance data of fissile isotopes in fast and thermal benchmarks

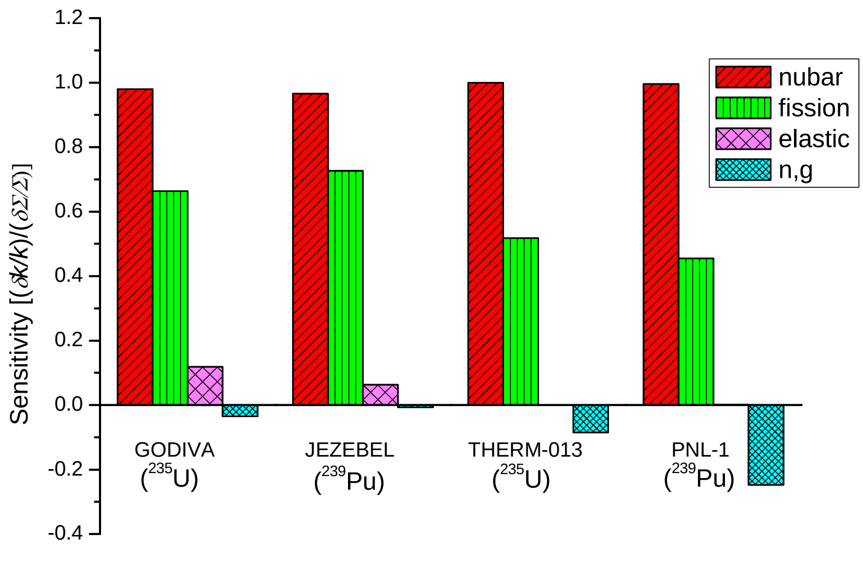

Figure 1. Sensitivities to k_{eff} with the fissile isotopes on the benchmarks

The analysis of sensitivity and uncertainty has also been extensively performed with the SUSD3D code.[9,10] The results of this analysis will be presented in the full paper. In addition, comparisons of the results of the SUSD3D and TSUNAMI codes and the ERRORJ and PUFF-IV codes will be presented. The calculations will also be presented for several fast and thermal benchmarks systems.

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