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GENERATION AND VALIDATION OF A WIMSD-5B MULTIGROUP CONSTANTS LIBRARY BASED ON JENDL-3.3 NUCLEAR DATA

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Abstract

This study deals with the benchmark analysis of a cross section library generated from Japanese evaluated nuclear data library (JENDL)-3.3 for the winfrith improved multi-group scheme (WIMS) D-5B code system by calculating the theoretical results of the integral parameters for TRX and BAPL benchmark lattices of thermal reactor. The nuclear data processing is performed by a new executable NJOY99.0. The integral parameters of five uranium-fuel thermal assemblies TRX-1, TRX-2, BAPL-UO2-1, BAPL-UO2-2, and BAPL-UO3-3 have been investigated using the latest version WIMSD-5B of the reactor lattice transport code WIMS. The calculated results are compared with those of experiments and it was found that the calculated integral parameters are in good agreement with the experimental results as well as with the other previously published values.

Keywords: NJOY99.0, JENDL-3.3, TRX and BAPL Benchmark Lattices, Integral Parameters, and WIMS D-5B.

Introduction

Winfrith improved multi-group scheme (WIMS) (Askew, 1966) is one of the most widely used general purpose thermal reactor analysis code available on non-commercial basis. The supporting WIMS cross section library being very old provides a scope for improvement of reactor calculation results by generating WIMS library based on latest release of the evaluated data files, such as; ENDF/B-VII (Chadwick, 2006), JENDL-3.3 (Asami, 2002) and JEF-2.2 (Lemmel, 1993) etc. Cullen's work (Cullen, 1989) proved many of the data processing codes to be obsolete. After careful analysis of these facts NJOY99.0 (MacFarlane, 1999) was chosen since it includes sophisticated methods of

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correct reconstruction using multi-level breit-wigner resonance parameters, Doppler broadening by accurate point kernel method, group to group thermal scattering matrices and special thermal law treatment. In addition the NJOY99.0 has capability to handle ENDF-6 format (Rose, 1990) which is used in ENDF/B-VII and several other basic data files. NJOY99.0 also provides a sophisticated and wider scope for "THERMR" treatment incorporating S (α,β) data in ENDF/B-VII. Some of these scattering law data is extremely important for TRIGA reactor calculations.

To validate the generated multi group library TRX 1-2, BAPL1-3 (CSEWG, 1981) benchmark lattices have been analyzed. A seven-group library of group constants to support CITATION (MacFarlane, 1994) calculations has been generated using the WIMSD-5B for neutronic analysis of 3 MW TRIGA research reactors. The generated library has been used for specific practical applications for validation purposes.

Methodology

Nuclear Data Processing

The processing of nuclear data files to generate cross section library through NJOY is a very sophisticated state-of-the-art technology in the field of nuclear science and technology. NJOY takes the basic data from the nuclear data library and converts them into forms needed for applications. The NJOY 99.0 (MacFarlane, 1999), latest version of NJOY. For WIMS library generation, the modules of NJOY are in following sequence: 'NJOY-MODER-RECONR-BROADR-UNRESR-THERMR-GROUPR-WIMSR'.
A flow diagram of the processing scheme is shown in Fig. 1

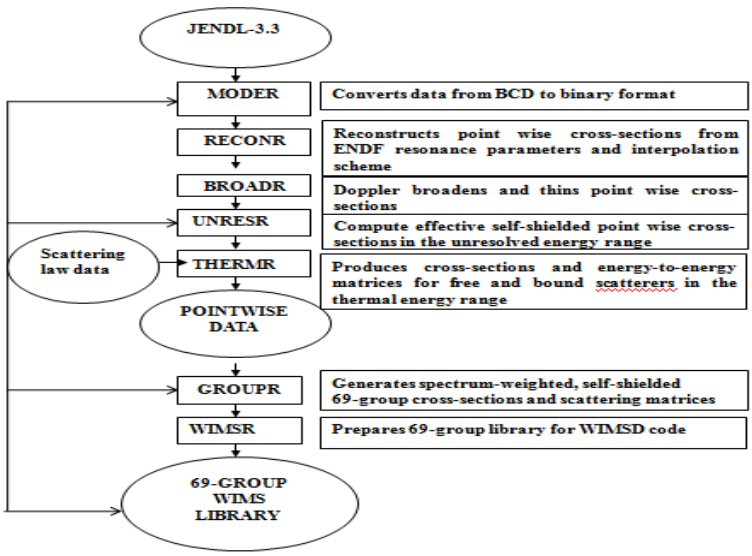

Fig. 1. Flow diagram for generating 69-group WIMS library.

Description of the Benchmarks

To study the quality of the nuclear data and the tools for analysis, the calculated integral parameters are often compared to the measured values of the benchmark experiments TRX & BAPL.

A. System description of TRX

These benchmarks are water moderated uranium critical lattices of slightly enriched (1.3 wt. %) uranium rods with diameters of 0.983 cm in a triangular pattern.

B. System description of BAPL

These experiments consist of H_2O moderated uranium oxide critical lattices of 1.311 wt. % enriched uranium oxide rods with diameters of 0.973 cm in a triangular pattern.

Table 1. Physical properties of TRX.

Region	**Outer radius (cm)**	**Isotope**	**Concentration** ($\times 10^{24}$ atoms/cm^3)
Fuel	0.4915	^{235}U	6.2530×10^{-2}
		^{238}U	4.7205×10^{-2}
Void	0.5042	--	--
Clad	0.5753	Al	6.025×10^{-2}
Moderator	‡	$^{1-}$H	6.676×10^{-2}
		^{16}O	3.338×10^{-2}

* lattices spacing of 1.8060 and 2.1740 cm respectively in triangular arrays

Table 2. Physical properties of BAPL.

Region	**Outer radius (cm)**	**Isotope**	**Concentration** ($\times 10^{24}$ atoms/cm^3)
Fuel	0.4864	^{235}U	3.112×10^{-2}
		^{238}U	$2.3127^2\times10^{-2}$
		O	4.6946×10^{-2}
Void	0.5042	--	--
Clad	0.5753	Al	6.025×10^{-2}
Moderator	‡	H	6.676×10^{-2}
		O	3.338×10^{-2}

* Lattices spacing of 1.5578, 1.6523 and 1.8057 cm respectively in triangular arrays

Parametric studies

The integral parameters calculated using the new JENDL-3.3 based WIMS library are as follows:

k_{eff} = Effective Multiplication Factor

ρ^{28} = Ratio of epithermal to thermal ^{238}U captures

= $(\Sigma_c)^{38}_{epth} / (\Sigma_c)^{38}_{th} = (\Sigma_a\text{-}\Sigma_f)^{38}_{epth} / (\Sigma_a\text{-}\Sigma_f)^{38}_{th}$

δ^{25} = Ratio of epithermal to thermal ^{135}U fission

= $(\Sigma_f)^{35}_{epth} / (\Sigma_f)^{35}_{th}$

δ^{28} = Ratio of ^{238}U fissions to ^{235}U fissions= $(\Sigma^t_f)^{38} / (\Sigma^t_f)^{35}$

C' = Ratio of ^{238}U captures to ^{235}U fissions

= $(\Sigma^t_c)^{38} / (\Sigma^t_f)^{35} = (\Sigma^t_a\text{-}\Sigma^t_f)^{38} / (\Sigma^t_f)^{35}$

Results and Discussions

The comparison among the calculated k_{eff} values with the experimental results, the original WIMS library and previously calculated in LANL (Mac Farlane, 1994) for TRX and BAPL benchmarks are shown in Table 3.

Table 3. Comparison of k_{eff} calculated from different libraries and experiment.

Assembly	ENDF/B-VI (LANL)	WIMS	Experimental	Calculated (JENDL-3.3)
TRX-1	0.9869(-1.31) †	1.0023(0.23) †	1.0000(0.30) *	0.9866(-1.33) †
TRX-2	0.9891(-1.09)	0.9966(-0.34)	1.0000(0.10)	0.9882(-1.17)
BAPL-1	0.9949(-0.51)	1.0030(0.30)	1.0000(0.10)	0.9979(-0.20)
BAPL-2	0.9959(-0.41)	1.0006(0.06)	1.0000(0.10)	0.9971(-0.29)
BAPL-3	0.9974(-0.26)	0.9982(-0.18)	1.0000(0.10)	0.9967(-0.33)

* Percentage of uncertainty in experimental measurements

† (Error in %) = [(Calculated value–Experimental value)/ Experimental value] × 100

Table-3 indicates that the k_{eff} for TRX and BAPL show better performance with the original WIMS library compared to other results as a whole. For BAPL-1, the calculated result is better than original WIMS and ENDF/B-VI (LANL) library. For BAPL-2, the calculated result is better than ENDF/B-VI (LANL) library. Comparison of the calculated integral parameters values for TRX with experiment and the original WIMS library, are summarized in Table 4.

Table 4. Summary of WIMS results based on JENDL 3.3 data for TRX benchmark lattices and comparison with experiment and the original WIMS library.

Lattice	ρ^{28}	δ^{25}	δ^{28}	C'
TRX-1 (Expt.)	1.320(1.6) *	0.0987(1.0)	0.0946(4.3)	0.797(1.0)
WIMS	1.26307(-4.31) †	0.09901(0.31)	0.09651(2.02)	0.77449(-2.82)
Calculated (JENDL-3.3)	1.33225(0.93) †	0.09616(-2.56)	0.09820(3.8)	0.79094(-0.75)
TRX-2 (Expt.)	0.837(1.9)	0.0614(1.3)	0.0693(5.1)	0.647(0.93)
WIMS	0.79671(-4.81)	0.06101(-0.64)	0.06951(0.30)	0.63207(-2.31)
Calculated (JENDL-3.3)	0.82759(-1.12)	0.05903(-3.85)	0.07008(1.13)	0.63681(-1.57)

* Percentage of uncertainty in experimental measurements

† (Error in %) = [(Calculated value–Experimental value)/ Experimental value] × 100

Table 4 shows that for TRX benchmark lattices the calculated results for ρ^{28} and C' are better than those of original WIMS. The percent of uncertainty is even less than the experimental uncertainty. For δ^{25} and δ^{28}, the original WIMS results are better than those of calculated results. Comparison of the calculated integral parameters values for BAPL with experiment and the original WIMS library, are summarized in Table 5.

Table 5 shows that for BAPL benchmark lattices original WIMS results for ρ^{28} and δ^{25} are better than those of the calculated results and vice-versa for δ^{28}.

Table 5. Summary of WIMS results based on JENDL 3.3 data for BAPL benchmark lattices and comparison with experiment and the original WIMS library.

Lattice	ρ^{28}	δ^{25}	δ^{28}	C'
BAPL-1 (Expt.)	1.390(.72) *	0.084(2.4)	0.078(5.1)	….
WIMS	1.345(-3.21) †	0.084(0.05)	0.075(-3.23)	0.795
Calculated (JENDL-3.3)	1.344(-3.27) †	0.809(-3.66)	0.075(-2.67)	0.789
BAPL-2 (Expt.	1.120(.89)	0.068(1.5)	0.070(5.7)	…
WIMS	1.122(0.24)	0.069(1.0)	0.065(-6.8)	0.728
Calculated (JENDL-3.3)	1.112(-0.62)	0.066(-2.84)	0.066(-6.48)	0.719
BAPL-3 (Expt.)	0.906(1.1)	0.052(1.9)	0.057(5.3)	….
WIMS	0.884(-2.32)	0.052(1.73)	0.053(-5.56)	0.653
Calculated (JENDL-3.3)	0.869(-4.00)	0.050(-2.23)	0.054(-5.61)	0.642

*Percentage of uncertainty in experimental measurements.

† Error in %) = [(Calculated value–Experimental value)/ Experimental value] × 100

Conclusion

In this study, the calculated integral parameters using JENDL-3.3, the experimental results, the original WIMS library and previously calculated in LANL for both the benchmark lattices are compared. By comparing the calculated results, good agreement is observed with negligible differences in some points. It is obvious that different evaluated nuclear data library is the cause of the difference between the calculated results. Therefore, it may be concluded that library JENDL-3.3 is sufficiently reliable for thermal reactor calculations for TRIGA Mark - II research reactor at AERE, Savar, Dhaka.

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References

Askew, J. R., Fayers, F. J. and Kemshell, P. B. 1966. A general description of the code WIMS, *Journal of British Nuclear Energy Society*, **86:**564-560.

Chadwick, M. B., Oblozinsky, P. and Herman M. 2006. ENDF/B-VII.0: next generation evaluated nuclear data library for nuclear science and technology. *Nuclear Data Sheets*. **107:**2931-3060.

Asami, T. Watanabe, T. Watanabe, Y. Igashira, M. Yamamuro, N. Kitazawa, H. Yamano, N. and Takano, H. 2002. Japanese evaluated nuclear data library version 3 revision-3: JENDL-3.3. *Journal of Nuclear Science and Technology*. **39:**1125-1132

Lemmel, H. D., Schwerer, O.1993. JEF-2.2: the evaluated nuclear data library of the NEA data bank IAEA-NDS-120, Rev. 2.

Cullen, D. E. 1989. Report on the IAEA cross section processing code verification project. IAEA-NDS-39.

MacFarlane, R. E. and Muir, D.W. 1999. NJOY99.0: Code system for producing point wise and multi-group neutron and photon cross-section from ENDF/B RSICC Code package PSR-480. Los Alamos national laboratory, Los Alamos, Mexico, USA.

Rose, P. F. and Dunford C. L. 1990. ENDF-102 data formats and procedures for the evaluated nuclear data file, ENDF-6. Brookhaven national laboratory report, BNL-NCS-44945, USA.

CSEWG: Benchmark specifications (With supplements). 1981. National Nuclear Data Center, BNL Upton, New York, USA, BNL-19302. **2:**202-206.

MacFarlane, R. E. 1994. Data Testing of ENDF/B-VI. Proceedings of international conference on nuclear data for science and technology. 2 Gatlinberg, Tennssee, USA.