Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Validation of WIMS-CANDU using Pin-Cell Lattices

Won Young Kim, Byung Joo Min and Joo Hwan Park
Korea Atomic Energy Research Institute, 150 Dukjin-Dong, Yousong-Gu, Daejourn, Korea

1. Introduction

The WIMS-CANDU is a lattice code which has a depletion capability for the analysis of reactor physics problems related to a design and safety. The WIMS-CANDU code has been developed from the WIMS-D5B, a version of the WIMS code released from the OECD/NEA data bank in 1998. The lattice code POWDERPUFS-V (PPV) has been used for the physics design and analysis of a natural uranium fuel for the CANDU reactor. However since the application of PPV is limited to a fresh fuel due to its empirical correlations, the WIMS-AECL code has been developed by AECL to substitute the PPV. Also, the WIMS-CANDU code is being developed to perform the physics analysis of the present operating CANDU reactors as a replacement of PPV.

As one of the developing work of WIMS-CANDU, the U^{238} absorption cross-section in the nuclear data library of WIMS-CANDU was updated and WIMS-CANDU was validated using the benchmark problems for pin-cell lattices such as TRX-1, TRX-2, Bapl-1, Bapl-2 and Bapl-3. The results by the WIMS-CANDU and the WIMS-AECL were compared with the experimental data.

2. Nuclear data library in WIMS-CANDU

The nuclear data library used in WIMS-CANDU has the structure of 69 energy groups for the nuclear reactor calculations. More than 170 materials from the evaluated nuclear data file are included. The data library was generated by the NJOY nuclear data processing system using the nuclear data file ENDF/B-VI. However the physics parameters calculated by the WIMS-CANDU with the previous library had a large discrepancy from the experiment and the WIMS-AECL prediction with ENDF/B-VI library. In particular, there is a large difference between the WIMS-CANDU and the experiment in the reaction rates related to the U^{238} absorption cross-section. Therefore the WIMS-CANDU library was modified on the basis of the nuclear data of the WIMS-AECL and compared with the WIMS-AECL prediction and experiments for the pin-cell model. In fact the U238 absorption cross-section in the new library is lower than those in the old one over the resonance neutron range as shown in the Figure 1.

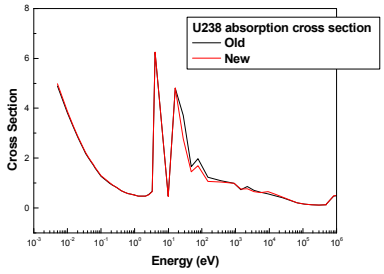

Figure 1 U^{238} absorption cross section

3. Pin-cell Benchmark Calculation

The TRX and BAPL lattices are the simple assemblies which are reduced to simulate a whole reactor operating at room temperature and moderated by the light water. The fuel materials of the TRX and BAPL lattices are 1.3wt% enriched uranium metal and uranium oxide, respectively. The pin-cell calculation was performed by the WIMS-CANDU with old and new libraries of 69-energy group and WIMS-AECL with 89-energy group library and the calculation results were compared with the experimental data. The compared parameters are the effective multiplication factors and the reaction rates.

Effective multiplication factor: The comparison of k_{eff} is given in Table 1. The averaged difference between the two WIMS-CANDU libraries is 1.0 and when compared with WIMS-AECL, the average differences are 1.2 and 2.3 from the WIMS-CANDU with old and new libraries, respectively. From the investigation of the present results, it is noted that the effective multiplication factors calculated by the codes such as WIMS-CANDU and WIMS-AECL were lower than the experiments, while the difference between WIMS-CANDU results with two kinds of libraries were not significant. Moreover the results of WIMS-CANDU show a relatively large discrepancy with the experimental data.

Reaction rates: The reaction rates are defined as follows:

ρ^{28}: the ratio of capture reactions in U^{238} above 0.625eV to those below 0.625eV
δ^{25}: the ratio of fission reactions in U^{235} above 0.625eV to those below 0.625eV
δ^{28}: the ratio of fission reactions in U^{238} to those in U^{235}
C*: the ratio of capture reactions in U^{238} to fission reactions in U^{235}

For ρ^{28}, the results of WIMS-CANDU with the new library show the excellent agreement with the experiment within 1.0% on average, while the average differences of WIMS-CANDU with old library and

WIMS-AECL with the experiment show 3.7% and ~1.9%, respectively. Also, the maximum errors of ρ^{28} are 3.66, 6.16 and 4.64 for the WIMS-CANDU with new and old libraries and the WIMS-AECL, respectively..

For δ^{25}, the results of WIMS-CANDU with the two libraries show a good agreement with the experiment data within 1.0% on average, which is slightly large compared with the WIMS-AECL (~0.56%). And the maximum errors are 1.95% and 1.67% in the case of TRX-2 and BAPL-1, respectively. The results of WIMS-CANDU calculation with the two libraries and WIMS-AECL calculation are lower than experiment for all cases.

For δ^{28} (fast fission factor), the maximum errors are 6.43%, 6.57% and 6.29% for the WIMS-CANDU with old library, with new library and the WIMS-AECL, respectively, when compared with the experiment. There are large discrepancies between the code calculations and the experiment, while the WIMS-CANDU with the two libraries is agreed well to the WIMS-AECL.

For C* (relative conversion ratio), the results of code calculations agree well with the experimental value for the cases of TRX-1 and TRX-2, whose maximum errors are 0.38%, 0.50% and 0.63% for the WIMS-CANDU with old library, with new library and the WIMS-AECL, respectively.

Table 1 Reaction Rates for Pin-cell Lattices

Lattice		k_{eff}	ρ^{28}	δ^{25}	δ^{28}	C*
TRX-1	EXP	1.0	1.320	0.0987	0.0946	0.97
	C-Old	0.99515	1.373	0.0979	0.0980	0.800
	C-New	0.99444	1.331	0.978	0.0982	0.801
	AECL	0.99614	1.354	0.0994	0.0987	0.792
TRX-2	EXP	1.0	0.837	0.614	0.0693	0.647
	C-Old	0.99531	0.862	0.0602	0.0700	0.645
	C-New	0.99417	0.834	0.0602	0.0701	0.649
	AECL	0.99658	0.845	0.0608	0.713	0.651
BAPL-1	EXP	1.0	1.39	0.084	0.078	
	C-Old	0.99894	1.428	0.0826	0.0760	0.813
	C-New	0.99804	1.396	0.0826	0.0760	0.813
	AECL	0.99992	1.394	0.0838	0.0762	0.809
BAPL-2	EXP	1.0	1.12	0.068	0.070	
	C-Old	0.99825	1.189	0.0675	0.0654	0.740
	C-New	0.99719	1.161	0.0675	0.0655	0.743
	AECL	0.99970	1.172	0.0682	0.0656	0.736
BAPL-3	EXP	1.0	0.906	0.052	0.057	
	C-Old	0.99813	0.9294	0.0519	0.0534	0.661
	C-New	0.99688	0.9064	0.0519	0.0537	0.664
	AECL	0.99990	0.917	0.0523	0.0538	0.657

* C-Old/New means the WIMS-CANDU code with Old/New libraries.

4. Conclusion

The nuclear data library of the WIMS-CANDU was updated considering the U^{238} absorption cross-section data and the benchmark calculation was performed for the pin-cell lattices. The codes used for the benchmarking are the WIMS-CANDU with the two different libraries of 69 energy groups and the WIMS-AECL with the library of 89 energy groups. The physics parameters such as the effective multiplication factor and four reaction rates were examined for the pin-cell lattices.

Regarding the effective multiplication factor, the results from the code calculations have no significant differences among them but the values are lower than the experiment, with maximum error of 2.3. For ρ^{28}, the WIMS-CANDU with the new library and the experiment agrees well due to the reduction of U^{238} resonance absorption cross-section in the new library of WIMS-CANDU by 1.0% on average and of maximum error 3.66%. For δ^{25}, the WIMS-CANDU show a good agreement with the experiment within 1.0% on average but this is a slightly large difference compared with the WIMS-AECL (about 0.56%). It needs to reconsider the fission cross-section of U^{235} in order to improve the prediction accuracy in WIMS-CANDU. For δ^{28} (fast fission factor), the large discrepancies between the code calculations and the experiment were found. It is noted that the fission cross-section of U^{238} in the libraries used in WIMS-CANDU should be investigated further. For C*(relative conversion ratio), the results by the codes agree well with the experiment in the case of the TRX-1, -2 and there is a good agreement between the WIMS-CANDU and the WIMS-AECL for the other cases.

Acknowledgement

The authors would like to express their appreciation to the Ministry of Science Technology (MOST) of the Republic of Korea for support of their work through the mid- and long-term nuclear R&D Project.

References

[1] J. R. Askew, "The Calculation of Resonance Captures in a Few-group Approximation", United Kingdom Atomic Energy Authority, AEEW-R 489, 1966.
[2] J. R. Askew, F. J. Fayers and P. B. Kemshell, "A general description of the lattice code WIMS", J. of the Brit. Nucl. Energy Soc. 5, 4(1966).
[3] J. V. Donnelly, "Description of the Resonance Treatment in WIMS-AECL", Atomic Energy of Canada Limited Report, AECL-10550, 1993.
[4] J. V. Donnelly, "WIMS-CRNL: A User's Manual for the Chalk River Version of WIMS", Atomic Energy of Canada Limited Report, AECL-8955, 1986.