Consistent Generation and Verification of 190 Group Cross Section Library Data for Primary Nuclides

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1. Introduction

The multigroup cross section data used in the lattice transport or the direct whole core transport codes such as HELIOS and DeCART have a significant impact on the accuracy of the criticality prediction. If a large discrepancy is noted in the analysis of critical experiments, it is customary to adjust the resonance integral (RI) data of U-238 given in the cross section library in order to match the measurement.[1] In case of HELIOS, the unadjusted library gives about 300~550 pcm lower reactivity than the adjusted one. The sole adjustment of the U238 RI, however, is to blame only U238 for all the discrepancies that can originate from various sources. One of the sources of the error would be the inaccuracy of subgroup parameters used in the a group codes which employ the subgroup method for resonance treatment. The inconsistency problem noted in the subgroup parameter generation and usage steps which was reported in our previous work[2] can be smeared out by the RI adjustment. Thus such blind adjustment of the resonance integral is to be avoided.

In this work, we examine a new procedure for generating multigroup cross section data from the ENDF/B files, which would not require any forced adjustment. One of the distinct steps in the procedure is to employ a consistent method of generating subgroup parameters formulated by imposing a shielded cross section conservation principle rather than the resonance integral conservation.[2] In order to check the validity of the procedure, multigroup data are generated only for a group of primary nuclides which appear in a fresh fuel UO_2 pin cell, namely, U-235, U-238, H-1, O-16, and Zr. The accuracy of the new library is assessed by comparing the reactivity with those obtained from corresponding continuous energy Monte Carlo calculations. Since recently the ENDF/B-VII file was released which reflects improvements in the U238 resonance data, the difference between the multigroup cross section libraries generated from the new ENDF file and its previous version (ENDF/B-VI Release 8) is also assessed.

2. Library Generation Procedure

The generation of the groupwise cross section data other than the subgroup parameters is rather straightforward as long as the groupwise cross section data are available from the NJOY runs. However, a suitable processing of the GROUPR output is necessary because 1) the groupwise cross sections generated by GROUPR represent all kinds of detailed possible reactions, 2) the transport cross section which is not a real reaction cross section should be properly obtained, and 3) there are some other data such as fission spectra which are not directly available from the GROUPR output. Thus a utility code named LIBDEC was written for the post processing of the GROUPR output in the format specific to the DeCART library. As the spectrum needed for group collapsing in GROUPR, a specific spectrum generated by an MCNP run for a typical PWR pin cell is used rather than those contained in the NJOY code such as the EPRI cell spectrum. This is to reflect more realistic spectrum suitable to specific applications.

For the subgroup parameter generation, the shielded resonance cross sections are generated first for a set of cylindrical pin cell problems using the RMET21 slowing down calculation code.[3] The cell dimension and/or the fuel to moderator ratio are varied to represent different dilution conditions. The effective cross section is used in a DeCART fixed source problem calculation to determine the corresponding background cross section. The shielded cross section vs. background cross section data are fitted using a least square method employing the subgroup formula to determine the subgroup weights. This is done by a program named GENOM. The procedure of generating groupwise cross sections and subgroup parameters are shown in Figure 1.

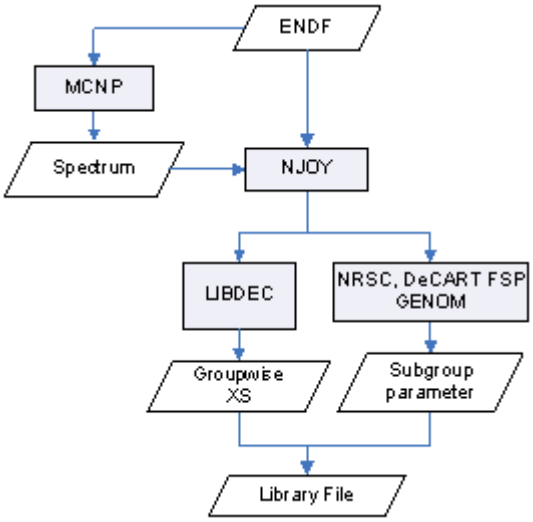

Figure 1. Library Generation Procedure

3. Verification

A typical Korea Optimized Fuel Assembly (KOFA) fuel pin cell with 4.95w/o enriched UO_2 fuel was used to generate the spectrum for the GROUPR processing by the MCNP code. The MCNP- generated 190 group spectrum is compared with the EPRI cell spectrum contained in NJOY. The point-wise spectrum to be

specified in the input was obtained by interpolating the groupwise spectrum. It is noted that the thermal spectra are quite different.

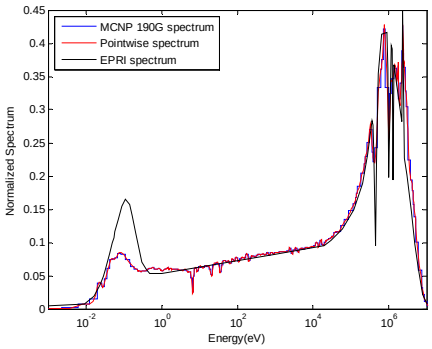

Figure 2. Spectrum comparison

Two multigroup cross section libraries, one for ENDF 6.8 and the other for ENDF 7.0, were generated according to the procedure described above. The MCNP cross section files were also generated separately from the two ENDF files at 6 different temperatures for the fuel isotopes: 296K, 634K, 764K, 958K, 1186K, and 1142K. These temperatures correspond to the average fuel temperature at different power levels. A pin cell problem which represents a KOFA fuel pin was then solved with different fuel temperatures and fuel enrichments (4.95 w/o and 1.50 w/o) by the DeCART and MCNP codes. The two HELIOS 190 G libraries, the adjusted one and unadjusted one, were also used in the test cases. The reactivity variation versus square root of the fuel temperature is shown in Figures 3 and 4 for the two enrichment cases.

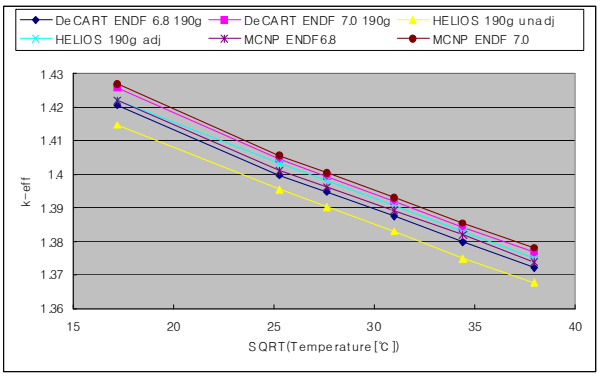

Figure 3. Reactivity vs. Fuel Temperature for 4.95 w/o

In these figures, the MCNP ENDF 7.0 cases are considered the most accurate one. First of all, it is noted that the slope of the variation which would determine the Doppler temperature coefficient is all similar and thus the difference at one temperature point can be applied to other points. The k-effective values and differences obtained for a middle temperature point, 764K, are given in Table I.

As appeared in the two figures, the unadjusted HELIOS library gives about 400~550 pcm lower k-eff than the adjusted one. The consistently generated libraries, however, match quite closely the corresponding MCNP cases. As shown in Table I, the difference from the MCNP case is about 100 pcm with the old ENDF (6.8) data. But it is reduced to about 50 pcm with the new one. This much difference is considered quite small. It is interesting to note that the reactivity increases about 200~450 pcm with the new ENDF data.

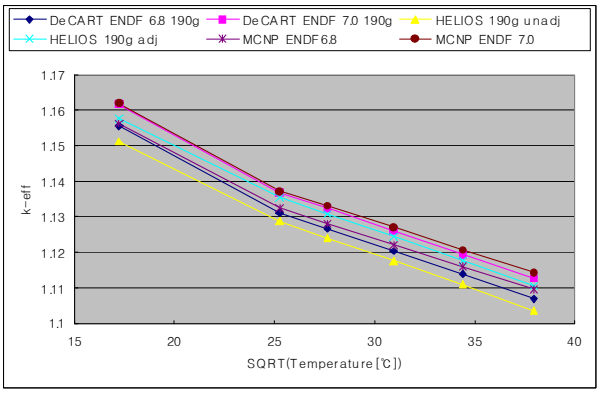

Figure 4. Reactivity vs. Fuel Temperature for 1.5 w/o

Table I. k-effectives for the 764 K Case

ENDF Version	4.95 w/o			1.5 w/o		
	MCNP	DeCART	Diff.	MCNP	DeCART	Diff.
6.8	1.39627	1.39469	-81	1.12826	1.12677	-117
7.0	1.40033	1.39943	-46	1.13320	1.13249	-55
Diff.	208	243		386	448	

- Difference given in pcm

4. Conclusion

With the new library generation procedure involving the consistent subgroup parameter generation, the agreement between the DeCART multigroup calculation and MCNP continuous energy calculation is within 120 pcm regardless of the ENDF version. Thus accurate library generation is possible without RI adjustment following the procedure reported here.

References

[1] U. Decher, Users Manual for LIBPRE: DIT Cross Section Library Preparation, Nuclear Data Project Report NDP-121, ABB Combustion Engineering Nuclear Fuel, Windsor, CT, USA.

[2] L. Pogosbekyan, H. G. Joo, C. H. Kim, and K. S. Kim, "Generation of Subgroup Weights Employing Shielded Cross Section Conservation Principle for Representative Pin Cells," M&C + SNA 2007, Monterey, California, April 15-19, 2007, on CD-ROM.

[3] F.Leszczynski. "Neutron Resonance Treatment with Details in Space and Energy for Pin Cells and Rod Clusters", *Ann.nucl.Energy*, **14**, 580-601, 1987.