Accuracy Improvement of Multigroup Cross section Library Data

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1. Introduction

In our previous work, the library generation procedure employing a consistent subgroup parameter generation procedure was established. [1,2] Even though the subgroup parameters were generated consistently, however, the resulting library involved about 400~500 pcm lower reactivity then correct one even for a pin cell problem than the reference ones. This work is to sort out the factors that induce such large errors and then to actually reduce the error by suitable measures. Especially we focus on the resonance parameters because it was confirmed that the groupwise XS induces little error by several tests.

2. Methods

Several attempts were carried out to reduce the error and the following four factors were identified as the primary contributors. A typical Korea Optimized Fuel Assembly (KOFA) fuel pin cell with 4.95 w/o enriched UO_2 fuel was used in this examination.

2.1 Zirconium Resonance

Even though resonances exist for the Zirconium isotope in the tens and hundreds keV range as shown in Figure 1, Zirconium was not treated as a resonance isotope in DeCART. Thus the absorption XS of Zirconium was generated merely by the GROUPR module of NJOY assuming infinite dilution of Zirconium. It can be one of the reasons to induce the error of XS library data. To confirm the effect of Zirconium resonances, the shielded absorption XS was generated by using the RMET21 code and replaced the GROUPR generated ones. As shown in Figure 1, the shielded cross section (black line) is substantially lower than the unshielded ones (red line).

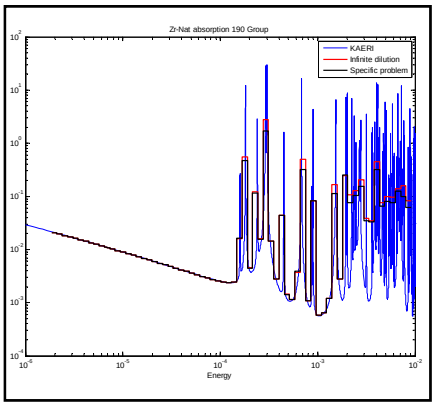

Figure 1. Effect of Self Shielding in Zirconium

2.2 Wigner-Seitz cell approximation [2]

RMET21 uses the collision probability method to solve the slowing down equation. For the analytic solution of the collision probability method, the 1-D cylindrical geometry is employed instead of the square cell. Namely, the Wigner-Seitz cell approximation is used to conserve the equivalence between the square and circular geometries. Because the Wigner-Seitz cell approximation is not exact, the error occurs in the shielded xsec as well as the multiplication factor. The magnitudes of each error component are shown in Table 1. The cross section here represents the shielded cross section over the entire resonance range. All these data were obtained by the MCNP calculations.

Table I. Error due to 1D cylindrical representation

Type	keff	U-238 Capture XS	U-235 Capture XS	U-235 Fission XS
Square	1.42207	2.144	11.286	19.330
Circle	1.41823	2.165	11.326	19.384
Error	384 pcm	1.0%	0.4%	0.3%

* Standard deviation of k-eff : 7 pcm

To eliminate this discrepancy, the equivalence radius of the fuel pellet was obtained by adjusting the size of the fuel region while keeping the total fuel amount the same. As shown in Figure 2, reductions in the pellet radius down to 0.3750 cm from the regular radius 0.4025 cm were necessary. This amounts to a maximum relative difference of 7%. The new library was generated with this equivalence radius and tested.

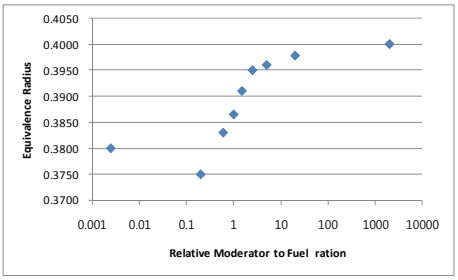

Figure 2. The equivalence radius via relative moderator to fuel ration

2.3 Cross Section Treatment in Slowing down calculation [3]

There is interaction between the resonances of different isotopes and it is considered in the transport code that uses the XS library. That's why we performed the RMET21 slowing down calculation with the resonance cross section of the isotope of interest. However it was noted that the presence of U-238 has so strong effect on the shielded cross section of U-235 as can be identified in the spectrum plots obtained with

and without U238. Thus this influence of U238 resonances should be incorporated in the transport code. And the shielded cross sections of U-235 should be calculated with the presence of U-238. And pointwise XSs of other isotopes like H-1, O-16 and Zr-nat are also are required to represent the energy dependence of scattering cross section.

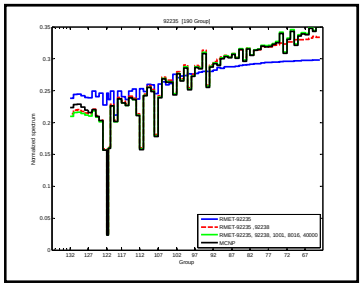

Figure 3. RMET21 spectra obtained with various combinations of isotopes

2.4 The ray parameter

The error in the multiplication factor can occur due to the accuracy of the transport solution obtained after the MG cross sections are fixed. In DeCART, MOC is used for transport calculation and the accuracy of the MOC solution depends on the number of rays. By increasing the number of discretized angles and reducing the ray spacing, we could generate spatially converged solution. The ray spacing and number of angles of the converged solution are 0.02, 16 and 8, respectively.

3. Results

The impact of the four factors discussed above was examined step by step by solving the pin cell problem at different temperature conditions. The results are given in Table 2 and Figures 4 and 5. As shown in the table, the shielded cross section of Zr effect and the ray spacing parameters is of most importance. By these two about 230 pcm error can disappear.

Table II. k-effective for 764K

Case	keff	Error with MCNP	Improvement
MCNP	1.39627	0	
base	1.38757	449	
Add equivalence Rad.	1.38910	370	80
Add proper isotopes	1.39023	311	58
Add Zr effect	1.39261	188	123
Add ray option	1.39474	79	110

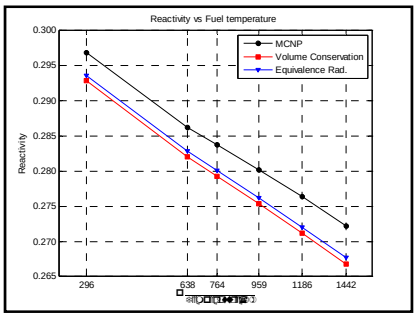

Figure 4. Effect of Wigner-Seitz Approximation

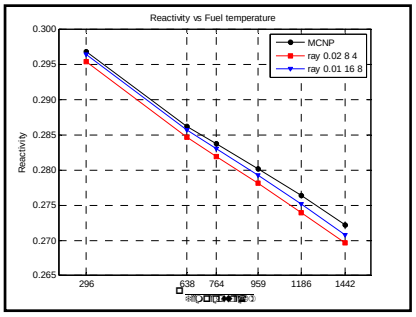

Figure 5. Effect of ray parameters

4. Conclusion

By identifying and correcting the four factors that can improve the error in the multigroup cross section, namely, the importance of self shielding in Zirconium, the equivalence radius, proper use of energy dependent cross section the slowing down calculation and the ray tracing parameter, the agreement between the MCNP and DeCART multigroup calculation is reduced from 450 pcm to 75 pcm. Thus a more accurate and consistent cross section library generation is now possible.

References

[1] Gwan Young Kim and Han Gyu Joo, "Consistent Generation and Verification of 190 Group Cross Section Library Data for Primary Nuclides", Transactions of the Korean Nuclear Society, Spring Meeting, Korea, May, 2008.

[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] Rudi J.J. Stammler, Methods of Steady-State Reactor Physics in Nuclear Design,40~41p,Academic press.

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