Search for Optimum Subgroup Levels for Minimizing Errors in Resonance Shielded Cross Sections

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1. Introduction

The subgroup method[1] is one of the most employed methods for resonance treatment in the lattice transport or the direct whole core transport codes such as HELIOS[2] and DeCART. It requires the subgroup parameters which consist of subgroup levels and subgroup weights. Subgroup weights are produced from the given subgroup levels by solving an error minimization problem for the resonance shielded effective cross sections[3,4]. The subgroup parameters have a significant impact on the accuracy of the effective cross section which is estimated by the subgroup method. The available subgroup levels for each resonance group of the existing libraries were not been thoroughly optimized. The purpose of this work is to devise a way to determine proper subgroup levels which can further reduce the error in the effective cross section errors. Needless to say, more correct resonance effective cross sections would improve the accuracy of the lattice transport or the direct whole transport calculation.

2. Methods and Results

HELIOS uses 7 subgroup levels as shown in Fig. 1 for U-238 with a 47 group structure including to 16 resonance groups.

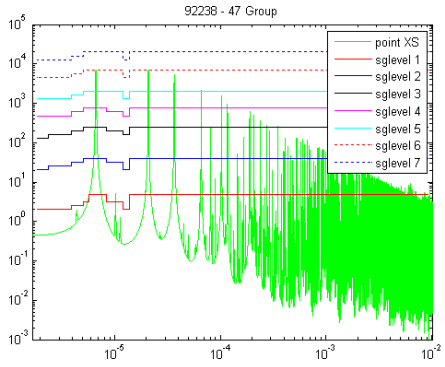

Fig 1.Existing subgroup levels of 47 HELIOS library and point wise absorption X-sec for U-238

It is indicated in Fig. 1 that most of the existing subgroup levels in the higher energy region are meaningless because many of them do not overlap with the pointwise absorption X-sec. It would be better if we can adjust properly the subgroup levels such that all of the 7 subgroup levels can overlap with the pointwise x-sec. In this section, we consider how to adjust subgroup levels automatically to achieve lower effective absorption x-sec errors.

2.1 Methods for searching the subgroup level automatically

First, to obtain a first set of meaningful 7 subgroup levels, we can divide equally the cross section range specified by the maximum and minimum levels for each resonance group, namely with 6 equal intervals. Then we can move the first level upward or downward by a certain fraction between the adjoining levels and then calculate subgroup weights according to the procedure developed to minimize the shielded cross section error [1]. With the two sets of subgroup parameters, obtain a new relative error in the effective x-sec. If the new relative error is lower than old one, the new subgroup levels are kept. Otherwise, keep the old one. The same is done for the other levels. If the relative error change is less than 10^{-3} after all level tested, refine the movement fraction by 1/10. This loop is repeated until fraction is lower than 10^{-5} or 25 iteration. The initial movement fraction is set by 1/10 in the log scale. A lower boundary level is needed for the first level to move downward. It is set to 0.01 times the initial first sublevel. Similarly, the upper boundary level is needed for the last level and it is set to 1.5 times the initial last level. For each level, 9 steps were moved and tested to the upward and downward directions.

2.2 New subgroup levels and relative error of effective resonance x-sec

The newly determined subgroup levels are shown in Fig.2 and they seem more reasonable than the old ones. The relative error in the U-238 groupwise effective resonance x-sec shown in Fig. 3 indicates that the error at important resonance groups (10^{-6} ~ 10^{-4}eV) reduced by more than 1/10.

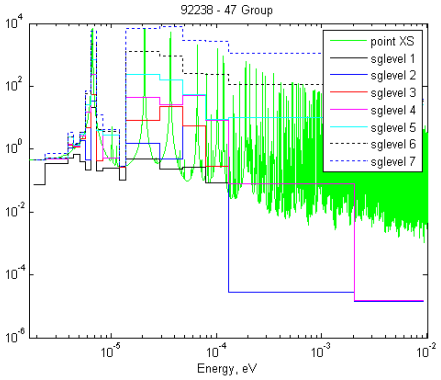

Fig 2.Optimized subgroup levels of 47 groups and pointwise absorption X-sec for U-238

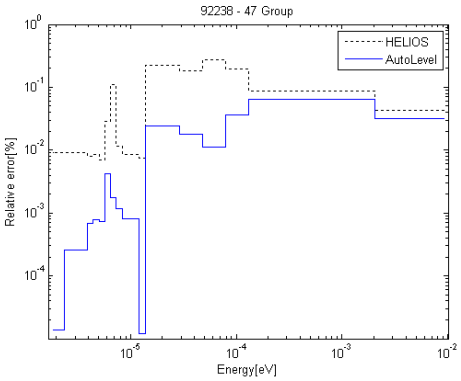

Fig 3.Relative error of effective resonance x-sec for U-238, one with old levels and the other with optimized levels

For U-235, the effective x-sec error of the new levels is also lower than the old ones at low energy region where wide resonance exists whereas at high energy group it is a bit higher. But considering that U-238 takes a significantly higher portion in fuel than U-235, the high error of effective x-sec for U-235 is judged to have less importance.

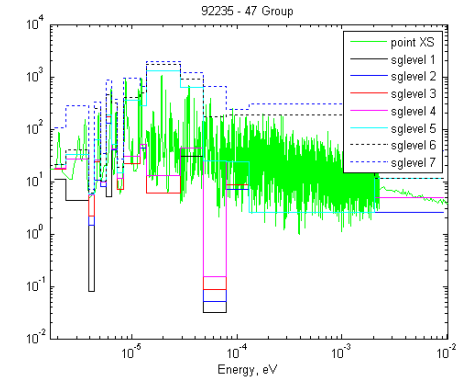

Fig 4.Optimized subgroup levels of 47 groups and pointwise absorption X-sec for U-235

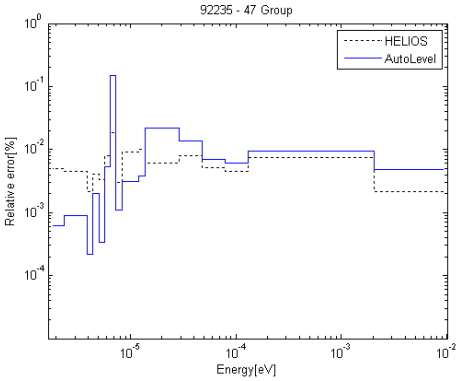

Fig 5.Relative error of effective resonance x-sec for U-235, one with old levels and the other with optimized level

2.3 Error of multiplication factor

The soundness of the new subgroup levels and weights is examined by solving the ROWLANDS benchmark problem. The multiplication factors from MCNP5 are taken as reference and compared with those of the optimized levels and also of the old level.

Fig. 6 shows that k-inf's from the optimized levels is more accurate than those from the old levels in that the error is reduced from 60~250 pcm to 15~140 pcm. However, considering that many factors effects on accuracy of the multiplication factor, we should admit that the reduction in the effective x-sec error doesn't always guarantee smaller k-inf errors. Reducing error of k-inf must be investigated independently along with other contributions.

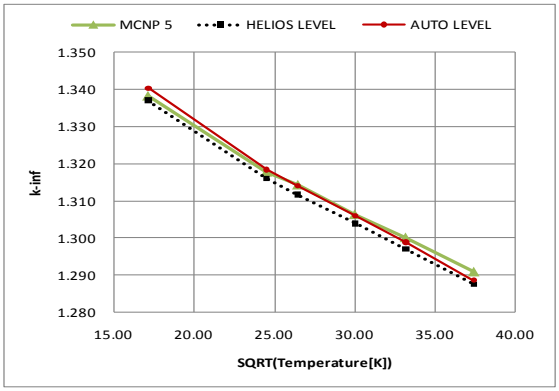

Fig 6.k-inf versus Fuel Temperature

3. Conclusions

An automated subgroup level search method to achieve minimization of errors in the resonance shielded effective cross sections has been developed. It turned out that the method works well in producing more reasonable subgroup levels which result in more accurate effective x-sec of U-238 than the old ones. These levels would improve the accuracy of the transport calculation codes which employ the subgroup method. Further improvement of the proposed method is however needed to reduce the error of U-235 effective x-sec at higher energies.

REFERENCES

[1] Cullen, D.E., 1974. Application of the probability table method to multigroup calculations of neutron transport. Nucl. Sci. Eng. 55, 387.
[2] Studsvik Scandpower, HELIOS Methods, Version 1.9, December 2005
[3] Han Gyu Joo, Gwan Young Kim, Leonid Pogosbekyan. (2009). Subgroup weight generation based on shielded pin-cell cross section conservation. "Annals of Nuclear Energy", 859-868.
[4] 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.