Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

A New Procedure for Resonance Integral Table with Pre-Adjusted Resonance Interference Effect for Transport Lattice Codes

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1. Introduction

Resonance treatment is the most important part in the deterministic transport lattice calculation. The conventional resonance treatment requires resonance integrals tabulated as a function of the background cross section (σ_b) or subgroup data transformed from the resonance integral table. Typically the resonance integrals for a nuclide are generated as a function of background cross sections through solving slowing down equation for 1-dimensional cylindrical fuel. Slowing down equation is solved for the very fine energy groups with scattering and absorption cross sections for resonant nuclide and potential cross sections for background nuclides. Resonance interference is considered not at this stage but at the transport calculation through the Bondarenko's iteration. This procedure results in some errors in predicting the interfered resonance cross sections. Sometimes the resonance integrals are adjusted from the comparison with the critical experiments such as TRX-1 and -2 and with other reference results to conserve the whole resonance reaction rate[1]. A new procedure has been developed to predict the group-wise self-shielded cross sections correctly. This procedure has been developed by using MERIT[1], SUBDATA[1], KARMA[2] developed at KAERI, and MCNP[3].

2. Methods and Results

2.1 Slowing down calculation

The typical energy range in a resonance nuclide for the resolved resonance is 0.5eV~10 keV where no fission source and no inelstic scattering can be assumed. Slowing down equation can be used in obtaining the self-shielded cross sections with a potential scattering cross section (σ_p), a resonance scattering cross section ($\sigma_{rs}(u)$) and a resonance absorption cross section ($\sigma_{ra}(u)$). Slowing down equation for region *k* can be written as follows:

$$\hat{\Omega}\cdot\nabla\psi_k+\sum_i\Sigma^k_{i,t}(u)\psi_k(u,\hat{\Omega})= \sum_i\int_{u-\Delta_i}^{u}\Sigma^k_{i,s}(u')\phi_k(u')\frac{\exp(u'-u)}{1-\alpha_i}du', \tag{1}$$

where

$$\begin{aligned}
&\Sigma_{i,x}=N_i\sigma_{i,x},\\
&\Sigma^k_{i,s}(u)=\Sigma^k_{i,p}+\Sigma^k_{i,rs}(u),\\
&\Sigma^k_{i,t}(u)=\Sigma^k_{i,s}(u)+\Sigma^k_{i,ra}(u),\\
&\alpha_i=(A_i-1)^2/(A_i+1)^2,\\
&\Delta_i=-\ln(\alpha_i).
\end{aligned} \tag{2}$$

2.2 Resonance Interference

KARMA adopts two different methods for the resonance treatments which are subgroup method and direct resonance integral (RI) method[4]. These two procedures share the same calculations to obtain equivalence cross sections and the resonance effects are considered by Bondarenko's iterations. Resonance interference in subgroup method is considered as follows:

$$\sigma_{ia}=\frac{1}{N_i}\frac{\sum_n w_{ni}\dfrac{\Sigma_{ian}\Sigma_{ibn}}{\Sigma_{ian}+\Sigma_{ix}+\Sigma_{ibn}}}{1-\sum_{j=all}\sum_n w_{jn}\dfrac{\Sigma_{jan}+\Sigma_{jx}}{\Sigma_{jan}+\Sigma_{jx}+\Sigma_{jbn}}}, \tag{3}$$

where Σ_{jx} is a total summation of other resonant nuclides. Since Σ_{jx} depend on Σ_{ia}, iterations are required. The iteration procedure is as follows:

$$\Sigma^{(0)}_{ix}\rightarrow\Sigma^{(0)}_{ia}\rightarrow\Sigma^{(1)}_{ix}\rightarrow\Sigma^{(1)}_{ia}\rightarrow\Sigma^{(2)}_{ix}\rightarrow\Sigma^{(2)}_{ia}\rightarrow . \tag{4}$$

Resonance interference in the direct RI method is considered as follows:

$$\sigma_{ia}=R_{ia}(\sigma_{ibx})\frac{\Sigma_{ib}+\Sigma_{ix}+\Sigma_{ia}}{\Sigma_{ib}+\Sigma_{ix}}, \tag{5}$$

where

$$\sigma_{ibx}=\frac{\Sigma_{ib}+\Sigma_{ix}}{N_i}. \tag{6}$$

The iteration procedure is performed by eq. (4).

2.3 Pre-adjustment for Resonance Integral

Resonance interference formulae of eqs. (3) and (5) cannot consider the real resonance interference exactly, which causes an error in estimating the self-shielded cross sections. Previously the RI adjustment method was proposed to conserve the total reaction rates for the whole resonance energy groups.[1] This method includes a drawback which is not to conserve self-shielded cross

section for each group. In this study a new method has been proposed to overcome the above drawback.

Key of a new procedure is to consider a part of interference in advance which cannot be covered by the resonance interference formulae. Figure 1 shows the overall procedure to perform RI adjustment by using the KAERI library processing system. RI table or subgroup data with no interference are used in estimating self-shielded cross sections and resonance interference is also considered in KARMA. The primary interfered results can be obtained and will be adjusted by the following.

The interfered reference results can be obtained by MCNP or MERIT with resonance interference. Resonance integral table can be adjusted to conserve the self-shielded cross sections with the reference results by using the following equation.

$$\tilde{R}_{ag}(\sigma_{bg}) = \frac{\Delta\sigma_{ag} + \sigma_{ag}(\sigma_{bg})}{1 + (\Delta\sigma_{ag} + \sigma_{ag}(\sigma_{bg}))/\sigma_{bg}}, \qquad (7)$$

where *g* is energy group, and *R* resonance integral.

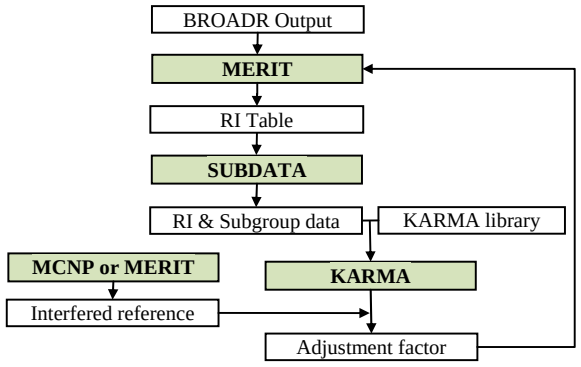

Figure 1. Procedure for RI adjustment

2.4 Calculation and results

RI table was generated without any resonance interference from which subgroup data was prepared. The KARMA calculations were performed and the interfered cross sections were edited. Adjustment factors were estimated through the comparison to the interfered reference solutions by which RI table could be adjusted. The corresponding background cross sections were estimated by MERIT again. The KARMA calculations are performed again with the adjusted one. It was shown that some iteration to obtain better results is not necessary and only one adjustment is enough, and re-evaluation of the background cross sections is also negligible. Figures 2 and 3 provide the comparisons of the multi-group cross sections for ^{235}U and ^{238}U in which subgroup method has been used. Relative errors have been reduced significantly and errors of various reactions rates between KARMA and MCNP could be negligible.

3. Conclusion

A new method to compensate the incomplete resonance interference has been devised. The computational results showed that this method enables not only to conserve group-wise self-shielded cross sections but also to conserve reaction rates.

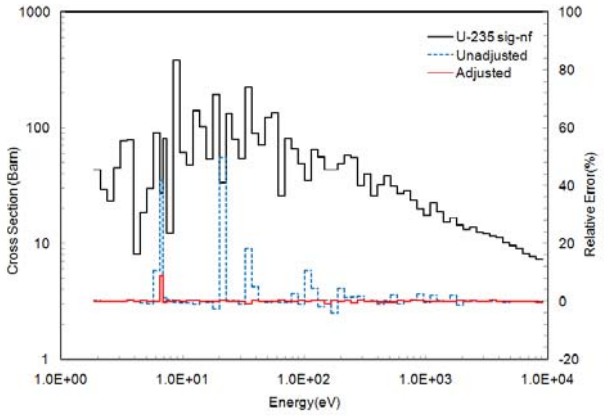

Figure 2. Comparison of the multi-group ν*fission cross sections for ^{235}U

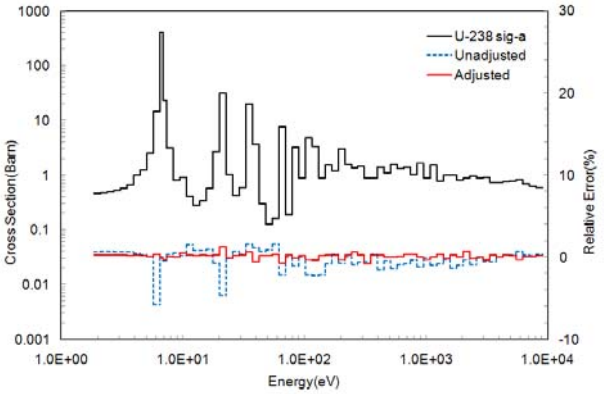

Figure 3. Comparison of the multi-group absorption cross sections for ^{238}U

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