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Improvements on MERIT 1.1 and SUBDATA 1.1 and a New Procedure for Resonance Integral Adjustment

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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) in advance or subgroup data transformed from the resonance integral table. MERIT[1] and SUBDATA[2] were developed to generate the resonance integral table and the subgroup data for KARMA[3] at KAERI. Recently these two codes have been improved significantly and a new procedure for the resonance data has been established.

Typically the resonance integrals for a nuclide are generated as a function of background cross sections. Slowing down equation is solved for the very fine energy groups with the scattering and absorption cross sections for the resonant nuclide and the potential cross sections for the background nuclides. Therefore resonance interference is considered not at this stage but at the transport calculation through the Bondarenko's iteration. This procedure results in big differences in the interfered resonance cross sections. Sometimes the resonance integrals are adjusted from the comparison with the critical experiments such as TRX-1 and -2. New procedures have been established to compensate the differences at the self-shielded cross sections.

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. Since fission neutron energy is mostly higher than 10 keV, no fission source can be assumed. There is almost no inelstic scattering in the neutron energy range <10 keV. The scattering source can be simplified by assuming isotropic scattering, only elastic scattering (s-wave) and no up-scattering. Slowing down equation can be simplified by introducing two assumptions that are generally valid in the resolved resonance range for reactor lattices.

a. Only one resonant nuclide is assumed in the mixture with a constant potential scattering cross section (σ_p), a resonance scattering cross section ($\sigma_{rs}(u)$) and a resonance absorption cross section ($\sigma_{ra}(u)$).
b. The non-resonant nuclides are considered to have negligible absorption and constant potential scattering cross sections.

Given the above assumptions, for region k, slowing down equation can be written as follows:

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

where

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

2.2 MERIT 1.1 and SUBDATA 1.1

Figure 1 shows the overall flow chart of KAERI library processing system to generate the KARMA library.

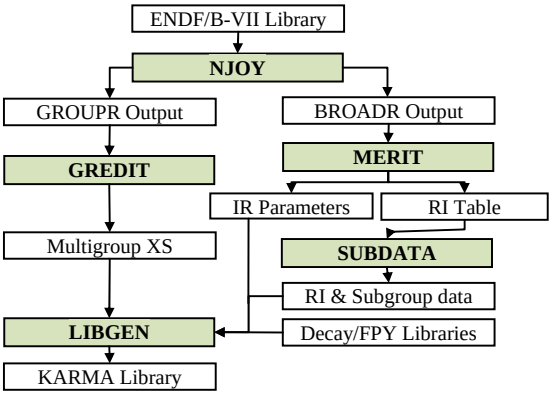

Figure 1. Flow chart for the library generation

MERIT has been modified to generate the intermediate resonance parameters (IRP) stably by checking the data fluctuation of cross sections and generating 1-g IRP, and to consider the multiple resonant nuclides to see the

resonance interference explicitly. The corresponding background cross sections can be generated by both the interface current method and the method of characteristics. In order to utilize a new method to generate the subgroup method, the level dependent background cross sections are generated at the new MERIT 1.1. Input deck has been modified to check all the possible user's errors.

Since there has been a discrepancy in between the generation of the subgroup data and the use of them, new method has been developed.[4] This method has been modified and implemented in the new SUBDATA 1.1. Input deck for SUBDATA 1.1 has also been modified to check all the possible user's errors.

2.4 Resonance adjustment

Reference pin cell calculations were performed by MCNP with the continuous cross sections from the same EMDF/B-VII for the 1.0~5.0% ^{235}U enrichment and 5 temperatures. Scalar fluxes and absorption and ν*fission cross sections of ^{235}U and ^{238}U were edited for the thermal, resonance and fast energy groups. Same calculations were performed by using KARMA 1.1 with the unadjusted 47-g and 190-g libraries, and scalar fluxes and absorption and ν*fission cross sections of ^{235}U and ^{238}U were edited for the same energy groups. Scalar fluxes of KARMA are renormalized to have the same power with those of MCNP, and then 3-g cross sections and reaction rates were compared with each other. There are reaction differences in ^{235}U absorption and ν*fission and ^{238}U absorption at the resonance group. Although the reaction rate difference is about 0.1 %$\Delta\rho$, absorption and ν*fission reactions were compensated by each other and then the influence on the eigenvalue could be negligible. Most of the eigenvalue difference comes from the ^{238}U absorption reaction rates as shown in Figure 2.

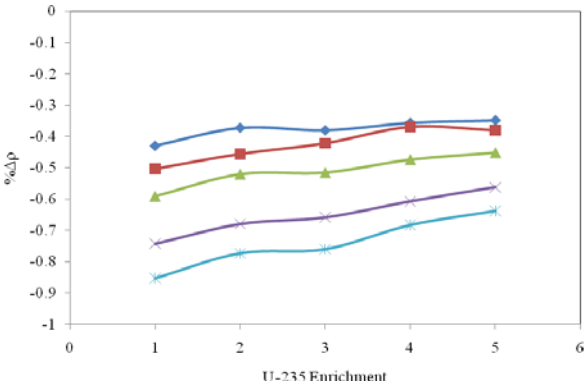

Figure 2. Absorption reaction rate difference of 238U

Resonance integral table for ^{238}U was adjusted to conserve the total reaction rates with the MCNP results by using the following equation.

$$\tilde{R}_{ag}(T,\sigma_{bg}) = \frac{\Delta\sigma_a(T) + \sigma_{a,g}(T,\sigma_{bg})}{1 + (\Delta\sigma_a(T) + \sigma_{a,g}(T,\sigma_{bg}))/\sigma_{bg}}, \quad (3)$$

where T denotes temperature, g energy group, and R resonance integral.

2.4 Calculation and results

Figure 3 shows the comparisons of the effective multiplication factors between KARMA and MCNP before and after adjustment. As shown in Figure eigenvalue differences have been reduced to be less than 100 pcm through the adjustment of the ^{238}U absorption cross sections at the resonance energy groups.

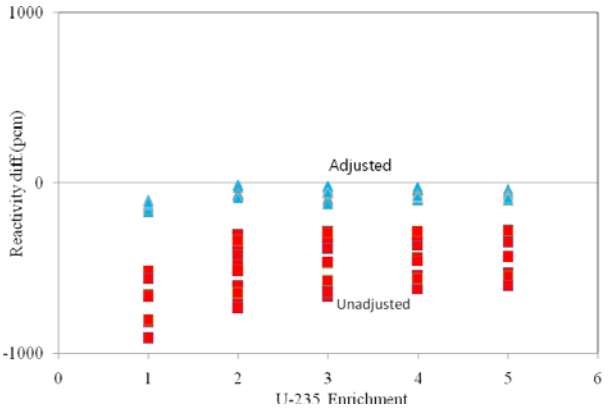

Figure 3. Comparison of the multiplication factors

3. Conclusion

MERIT and SUBDATA codes have been improved and a new procedure to generate the effective resonance integral table has been setup. It was shown that newly generated resonance integral table for 238U is working well.

REFERENCES

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