Determination of Intermediate Resonance Parameter with RMET21 for nTRACER

Muhammad Sohail [(1)] and Myung-Hyun Kim [(1)&(2)]
(1) Department of Nuclear Engineering, Kyung Hee University, 446-701, Rep. of Korea
(2) Reactor Engineering Division, Argonne National Laboratory, IL 60439, USA
mhkim@khu.ac.kr

1. Introduction

Ray Tracing based code nTRACER is being developed in Seoul National University that has the capability of 3-dimentional whole core neutron transport calculation. As a part of development of multi-group neutron cross section library for nTRACER, the current work is intended to accurately determine intermediate resonance parameters. Beside the systematic calculation of subgroup parameters for resonance self shielding calculation, intermediate resonance parameters itself can be as important as the multi-group neutron cross section in the library and its overall accuracy. In this paper lambda factors were computed using RMET21 from ENDF/B-VII.1 for nTRACER to investigate its dependence on temperature and background cross section and replaced with lambda factors from HELIOS multi-group library. The procedure used for determining the intermediate resonance parameter for the isotope under study is introduced in the next section. Oxygen being one of the primary nuclide in PWR fuel has been selected for intermediate resonance parameters calculation.

2. Intermediate Resonance Approximation

In this approximation, the fraction λ_i of the scattering for each isotope *i* is assumed to be so effective that the maximum lethargy gain per collision is significantly greater than the practical resonance width (i.e., the narrow resonance scattering) [1]. Conversely, the remaining fraction $(1-\lambda_i)$ is assumed to be so ineffective that neutrons gain a negligible amount of lethargy compared with Δ_{ug} (i.e., the wide resonance scattering). Thus, this fraction of scattering does not provide source neutrons from outside the resonance widths but it should be considered as due to self-scattering which neither adds nor removes neutrons. With these approximations, the slowing down equation for the coarse energy groups takes the form as [2].

$$\Omega.\nabla\psi_{g,k} + \sum_i \sum_{i,g,t}^{k} \psi_{g,k}(\Omega) = \sum_i \lambda_{i,g} \sum_{i,p}^{k} + \sum_i (1-\lambda_{i,g}) \sum_{i,g,s}^{k} \phi_{g,k} \quad (1)$$

2.1 Lambda factor Calculation Procedure

The procedure used in the work here to calculate lambda factors with respect to U-238 is as follows: [3]

1. Calculate absorption cross section $\sigma_{g,a}$ tables, by solving 1-D Resonance Slowing Down Equation using RMET21 for infinite homogenous U-238/H mixtures with various density ratio N_R: N_H i.e σ_0.
   Where $\sigma_0 = \frac{N_H}{N_R}\sigma_p^H$ (2)
2. For a non-hydrogen scattering isotope-*i*, Compute the slowing down calculation U-238/H/isotope-*i* mixture with density ratio N_R:N_H:N_i to obtain a new $\sigma_{g,a}$ for each resonance group.
3. Obtain the corresponding σ_0^{eq} from the prepared $\sigma_{g,a}$ table. Ultimately the group g lambda for isotope-*i* is then determined as
   $$\lambda_{i,g} = \frac{N_R\,\sigma_0^{eq} - N_H\,\sigma_p^H}{N_i \sigma_p^i} \quad (3)$$

2.2 Calculation with RMET21

The intermediate resonance parameters used are traditionally dependent only on neutron energy. However principally they are affected by the width of the resonances that motivates calculation of these factors at different temperature as resonances are highly sensitive to the temperature of resonance isotope. In this work computation of lambda factors was done for a range of operating temperatures in PWR. The average absorption cross sections of U-238 in the resonance groups were calculated with RMET21 and MCNP using the same PENDF library. The maximum difference is less than 0.6% which indicates accurate estimation of average absorption cross sections by RMET21. Fig. 1 shows the dependency of the group 19 absorption cross sections on σ_0 at different temperatures which indicates that average absorption cross section are highly sensitive to background cross section and are weakly dependent on the temperature of resonance isotope.

3. Calculation and Validation of Lambda factors

To accurately determine the intermediate resonance parameters, its dependency on the temperature of the resonance isotopes and the background cross sections (σ_0) should be properly investigated. Fig. 2 indicates that lambda parameters may depend on the background cross section therefore an average value of 30barns estimated from a typical PWR fuel pin was selected for lambda calculation [3]. Whereas Fig. 3 indicates that lambda factors are reasonably independent of the temperature of resonance isotope. It also indicates that lambda of Oxygen 16 computed using ENDF/B-VII.1 with RMET21 in groups 1-18 are close to values in HELIOS library based on ENDF/B-V. However, the lambda factors for groups 19-25 are considerably

different from HELIOS values. Lambda in group 23 showed different trend as U-238 has very small resonance peak in this group and due to lack of resonances in the groups 20-22, 24 and 25 the accurate computation of lambdas was not possible. In this case lambdas with respect to U-235 were computed with the same procedure except U-238 was replaced with U-235 and background cross section of 1000 barns was selected.

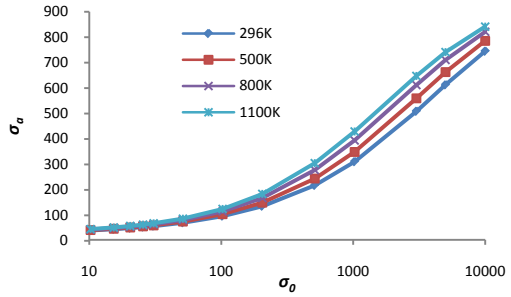

Fig. 1. U-238 average absorption cross section in U-238/H mixtures at group 19.

nTRACER multi-group library was first generated for the primary isotopes using the procedure demonstrated in Fig. 4. The computed Intermediate resonance parameters of oxygen for each resonance groups were then replaced in the nTRACER library for the calculation of K-eff value for a single lattice pin cell of PWR fuel. The results of K-eff value calculated using the new lambda factors were compared with MCNP which are summarized in Table 1.

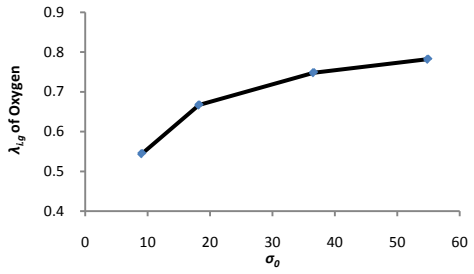

Fig. 2. Lambda of Oxygen at group 19 computed with different σ_0 values.

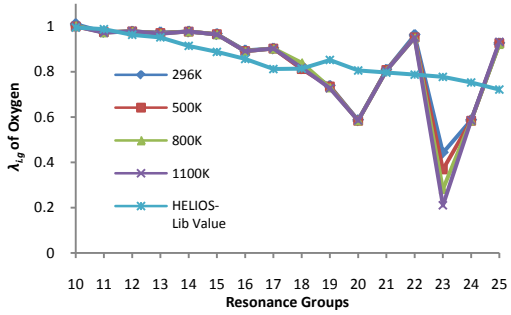

Fig. 3. Comparison of Lambda values of Oxygen at different temperatures with values in HELIOS Library

The results do not indicate any remarkable improvement in K-eff and maximum difference was less than 4 pcm with new lambda of Oxygen as it is not a strong resonance absorber and relatively smaller values of $\lambda\sigma_p$ compared with other primary nuclides in the PWR fuel pin. However with RMET21 for slowing down spectrum estimation from ENDF/B-VII.1 nuclear data, the new computed lambda factors can be used in the multi-group library.

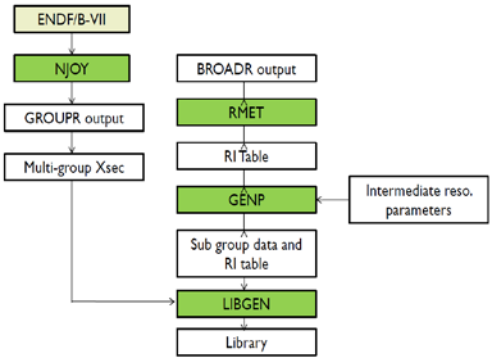

Fig. 4. Procedure for multi-group data library generation for nTRACER

Table 1. Comparison of K-eff values

Enrichment (w%)	nTRACER	MCNPX	Δρ(pcm)
3	1.41375	1.41312	31.2
4.5	1.51307	1.51244	27.5
6	1.5678	1.56738	17.1

3. Conclusions

The method used in this work for lambda factor calculation has shown satisfactory results. Therefore it can be used for more dominant resonance nuclide such as U-235 and U-238. Lambda factor of Oxygen showed weak dependence on the temperature of resonance isotopes because of lack of strong resonances of O-16. However, lambda factors of strong resonance absorber such as U-238 may have potential of considerable temperature dependency. Computation of lambda at actual background cross section values at each energy group instead of its average value over all energy groups of a typical PWR pin is set as future task of updating lambda factors from latest ENDF data as a part of development of multi-group data library for nTRACER. In addition the method also provides the option for computation of lambda with reference to U-235 in energy groups with small resonances of U-238.

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