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Resonance Treatment of ^{237}NP for Multi-Group Cross sections by Subgroup Method

Oh-Sung Shim, Muhammad Sohail and Myung-Hyun Kim
Department of Nuclear Engineering, Kyung Hee University, 446-701, Rep. of Korea
mhkim@khu.ac.kr

1. Introduction

The subgroup method or probability table method is applied for determination of self shielded resonance cross-sections without resorting to the intermediate calculation of Dancoff factors [1, 2]. Therefore it has advantage of simple and straight forward implementation for the cases of arbitrary geometry or direct whole-core transport calculation. The subgroup data is generated for resonant isotopes that exhibit large and complex variation of cross sections in the resonance energy range and occur in sufficient concentration. Normally in multi-group cross section library not all such isotopes are considered as resonant and therefore their subgroup parameters are not included. However some of these isotopes e.g. minor actinides become important if they are present in sufficient concentration to effect the self shielded calculation of other isotopes through resonance interference and accuracy of their own effective cross section. Therefore in order to investigate the effect of non resonant isotopes, various cases have been studied considering the ^{237}Np as resonant/non resonant isotope in the multi-group cross section library. The resonance data required for multi-group cross section library includes infinitely diluted resonance integral, subgroup levels and subgroup weights for ^{237}Np along with the smooth resonance data such as $\lambda\sigma_p$. These parameters are determined using RMET21 and GENP codes of the library processing system for multi-group cross section generation from ENDF/B.

2. Preliminary Check on Minor Actinide Resonance

nTRACER uses HELIOS library format which considers only ^{241}Am as resonant isotope of the minor actinides. However most of these actinides have high absorption cross section and some isotopes exhibit many resonances and have complex and large variation of cross sections in resonance energy range. The cross section behavior of some important minor actinides is shown in Fig. 1. The criteria that can be used for deciding the importance of an isotope as resonant absorber should include its abundance (in conventional spent fuel), resonance peaks (capture cross section at low resonance energy range) and cross section variation (for interference effect with ^{238}U and other predominant resonant absorbers)

In Table 1 the relative amount of various minor actinides is obtained with 3.2 w/o enriched UO_2 fuel at a Burnup of 940 days by ORIGEN code. Minor actinides such as ^{243}Am, ^{237}Np, ^{243}Cm, ^{244}Cm, ^{246}Cm and ^{248}Cm have high resonances in low energy with complex variation. Most of these isotopes are produced in negligible amount. Whereas ^{243}Am and ^{237}Np have relatively larger abundance than ^{241}Am which is already included as resonant absorber in the multi-group library. However ^{238}Np has large cross section and number of resonances as compared to ^{243}Am.

Table 1 : Resonance properties along with relative abundance in burnt PWR fuel of minor actinides

Isotopes	*Relative Amount (wt)*	*Resonance peaks (H/L)*	*Variation*
Am241	2.98E-03	H	C
Am242m	6.62E-05	L	N
Am242	1.02E-05	L	N
Am243	8.56E-03	H	C
Np237	4.31E-02	H	C
Np238	1.40E-04	L	N
Np239	9.51E-03	L	N
Cm242	1.28E-03	H	N
Cm243	3.51E-05	L	N
Cm244	2.93E-03	H	C
Cm245	8.55E-05	L	N
Cm246	1.02E-05	H	C
Cm247	9.09E-08	H	N
Cm248	0	H	C

H: high, L: low, C: complex, N: negligible

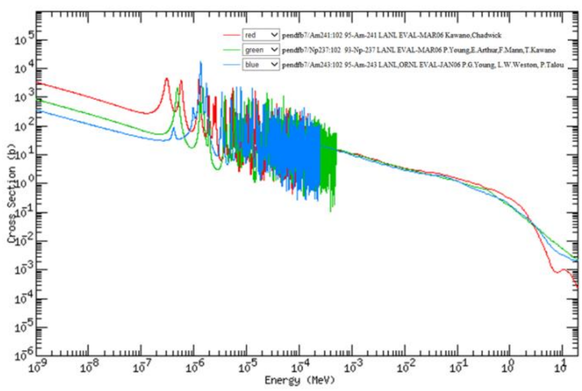

Fig.1. Principle cross section of some important minor actinides.

3. Calculation and Results

The fine group slowing down equation is solved for a homogenous mixture of heavy isotope and hydrogen as moderator. RMET21 code can perform the neutron slowing down calculations for homogenous and heterogeneous system at various temperature and dilution cases. These RI integrals and effective cross section are then used by GENP code to determine the subgroup weights. GENP solves the fixed source problem using intermediate resonance approximation to determine the subgroup level dependent background cross sections [3] before solving the constrained minimization problem as least square fit which is the final step of subgroup weights calculation. The overall procedure for generation of resonance parameters and multi group cross sections is shown in schematic of Figure 2.

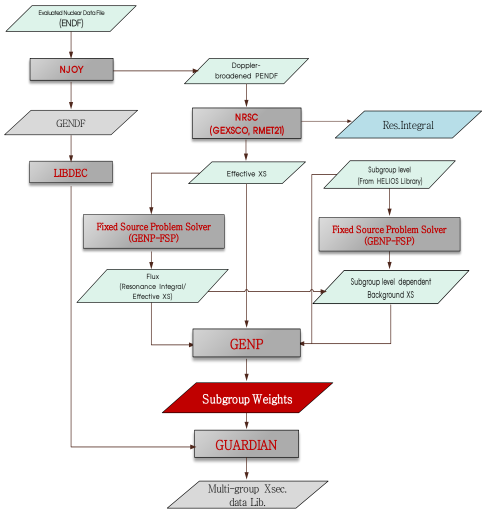

Fig. 2. Procedure for multi-group library generation

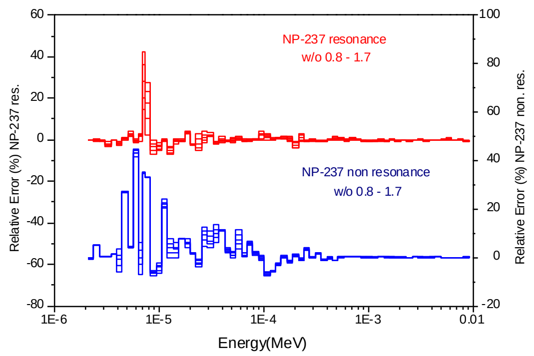

Fig. 3. Relative error of self shielded absorption cross section of ^{237}NP with various wt%

The calculations are performed for various compositions of ^{237}Np mixed with UO_2 fuel in a typical PWR reactor fuel pin. Direct whole core neutron transport code nTRACER is used for multi-group calculations to obtain the infinite multiplication factor and resonance self shielding cross sections. These results were then compared with MCNPX runs. Figure 3 provides the comparison of effective cross section of ^{237}Np in resonance energy range with MCNPX computed cross section at various ^{237}Np weight percent. The error is decreased in all energy groups when ^{237}Np is treated as resonance isotope by subgroup method. The results of reactivity difference with MCNPX runs are given in Table 2 for different cases. The results of case 1 and case 2 are obtained from the conventional treatment of ^{237}Np as non resonant isotope whereas case 2 additionally considers the resonance interference effect of ^{237}Np on uranium isotopes as an interim test. Case 3 includes ^{237}Np as resonant absorber with newly generated resonance parameters. The reactivity improvement parameter IMP is defined as the difference of absolute reactivity without modification i.e. ^{237}Np as non resonant (case 1) and absolute reactivity with modification (case 2 and 3). The reactivity difference with MCNPX is higher when ^{237}Np is conventionally treated as non resonant isotope (see case 1) as compared to case 2 and case 3 for various compositions. The reactivity difference decreases in case 2 by the magnitude given in parenthesis (IMP) when the resonance cross sections of ^{235}U and ^{238}U have contribution of resonance interference term of ^{237}Np in subgroup method to quantify the interference of ^{237}Np with other resonant isotopes. The improvement in case 2 is 12 to 43 pcm for 0.5 to 1.7 wt% of ^{237}Np. Finally ^{237}Np is treated as resonant isotope with its newly generated resonance parameters. Therefore the self shielded cross sections of all resonant isotopes including ^{237}Np were computed by subgroup method in case 3. The reactivity difference compared with reference MCNPX runs show further improvement. The minimum improvement was at 0.5wt% of ^{237}Np that increased upto 109 pcm at 1.7wt% which reduced the reactivity difference to only 3 pcm.

Table 2. Reactivity difference with MCNPX runs for different cases at various compositions

Comp.	***0.5wt%***	***0.8wt%***	***1.1wt%***	***1.4wt%***	***1.7wt%***
K_{inf} (ref)	***1.26791***	***1.22138***	***1.17933***	***1.14091***	***1.10616***
Δρ (IMP)					
Case 1	-177(-)	-195(-)	-190(-)	-177(-)	-113(-)
Case 2	-165(12)	-175(20)	-162(28)	-142(35)	-69(43)
Case 3	-154(23)	-154(41)	-129(62)	-91(87)	-3(109)

IMP: $abs(\Delta\rho)_{case\ 1} - abs(\Delta\rho)_{case\ 2/3}$
K_{inf} (ref): Infinite multiplication factor with MCNPX runs

4. Conclusions

The present work have shown that effective multi-group cross sections of non resonant isotope such as ^{237}Np if present in sufficient quantity can have influence on the accuracy of multiplication factor. The subgroup parameters are generated along with other multi-group cross sections for ^{237}Np. The cross section as well as the infinite multiplication factor showed more close results to MCNPX calculations when ^{237}Np is considered as resonant isotopes. It can be concluded that some other important non resonance isotopes can also be considered as resonant for improved cross section estimation and proper incorporation of their resonance interference effect by subgroup method.

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