Multi-Group Library Processing for the Transport Lattice Code KARMA

Ser Gi Hong, Kang-Seog Kim, and Jae-Seung Song
Korea Atomic Energy Research Institute, Duckjin-dong, Yuseong-gu, Daejon, Korea
hongsg@kaeri.re.kr, kimks@kaeri.re.kr, jssong@kaeri.re.kr

1. Introduction

KAERI has developed a transport lattice calculation code KARMA (Kernel Analyzer by Ray-tracing Method for Fuel Assembly) under the project "Development of the Major Design Codes for a Nuclear Power Plant" which is supported by Korea Ministry of Knowledge Economy. This project consists of two parts: the first part is to generate the multi-group cross section library using the library processing system developed by KAERI, and the second one is to develop a transport lattice code to generate the homogenized macro-group group constants for the following core analysis code. This paper is to report the current status, the programs, and some preliminary results of the multi-group library processing section for the KARMA code.

2. Description of the Procedures and Programs

The procedures and the programs for the KARMA multi-group cross section library are described in Fig.1. The ANJOY program[1] prepares the NJOY input files for all the nuclides which are to be used in the nuclear reactor physics analysis and a batch file for the automatic multiple NJOY[2] runs. The basic nuclear data file which is read from NJOY is the ENDF/B-VII.0. The NJOY runs generate two types of multi-group cross section files: the first one is the output file (multi-group format) of the GROUPR module which contains the multi-group cross sections versus the background cross sections and temperatures, and the other is the PENDF (point-wise format) output file of the BROADR module of NJOY which contains the point-wise (i.e., ultra-fine energy groups) cross sections versus temperatures.

The GREDIT program[3] generates a multi-group cross section file having a specific format after reading the output file of the GROUPR module of NJOY. This file contains the total, capture, fission cross sections, fission spectrum, Pn scattering matrices, delayed neutron fractions and so on.

The MERIT program[4] generates the resonance integral tables versus temperatures and the pre-described background cross sections for all the resonance nuclides after reading the PENDF cross section file generated from the BROADR module of NJOY. Another function of this program is to generate the hydrogen-equivalence factor[5] which is a parameter used in the intermediate resonance (IR) approximation[4,5]. The first step for the generation of the resonance integrals is to generate the hydrogen-equivalence factors : 1) A table set of the resonance integrals versus the background cross section is prepared by solving the slowing down equation for a homogeneous mixture of a target resonance nuclide and hydrogen, 2) The slowing down equation is re-solved to evaluate the resonance integral for the mixture where some fraction of hydrogen is substituted by a moderating nuclide, 3) The hydrogen-equivalence factor for the moderating nuclide is calculated by calculating the background cross section corresponding to the resonance integral for the new mixture with the prepared table set of resonance integral versus background cross section. After this step, MERIT generates the resonance integrals for a broad resonance group structure by the slowing down equations with a PENDF cross section file and a prepared library file containing the potential scattering and the hydrogen-equivalence factors. This calculation is performed for several variational cases that are prepared by changing the atomic number densities or volumes of fuel and moderator regions. Each case corresponds to a background cross section for each energy group. In fact, the background cross section is calculated by solving the slowing down equation with the IR approximation for a broad energy group structure. The final step of the MERIT calculations is to interpolate the resonance integrals for a set of given input background cross sections by using the table set of the resonance integrals versus the variational cases and the Segev's interpolation method.

KARMA uses the subgroup method for treating the resonance self-shielding. The SUBDATA program[6] generates the required subgroup data such as subgroup levels and weights by using a non-linear least square fitting method. In this fitting, the subgroup data are determined such that the resonance integrals at a given set of background cross sections are accurately approximated by the subgroup levels and weights. There are two types of subgroup data (i.e., four and seven levels) for each energy group. The subgroup levels (i.e., subgroup cross sections) do not depend on the temperature but the subgroup weights depend on it.

The final KARMA library is generated by the LIBGEN program[7] which reads the formatted output files of the GREDIT and the SUBDATA programs. This program also reads some information from the ENDF/B cross section, decay and fission product yield libraries and it re-evaluates some of these data by using raw data to obtain effective ones.

3. Preliminary Results and Conclusions

This section describes some of the preliminary results of the multi-group cross section processing programs of KARMA. Currently, a 190-group KARMA cross section library has been generated by using the procedures and programs described in the previous sections. In this energy group structure, the resonance region (1.855 eV~9.118 KeV) consists of sixty-nine energy groups. Fig.2 compares the hydrogen-equivalence factors for H-1, O-16, and U-238 calculated with MERIT. The figure shows that some energy groups have hydrogen-equivalence factors greater than unity, which are unphysical values. These unphysical values are from the fact that the resonance is not important in these groups and so, the resonance integrals are almost independent of the background cross sections. Therefore, the hydrogen-equivalence factors greater than unity do not affect the final results.

Fig. 3 and 4 compares the resonance integrals versus the background cross section which are obtained by the Segev's interpolation (MERIT), variational cases (MERIT), and HELIOS[7], respectively. From these figures, it is shown that 1) the Segev's method interpolates accurately the resonance integrals corresponding to the variational cases, and 2) the MERIT results have good agreement with those of HELIOS. As conclusion, the library processing programs for KARMA have been successfully developed and the preliminary results show good agreements with those of HELIOS.

Acknowledgement

This work is supported by "Development of the Major Design Codes for a Nuclear Power Plant" Project sponsored by Korea Ministry of Knowledge Economy.

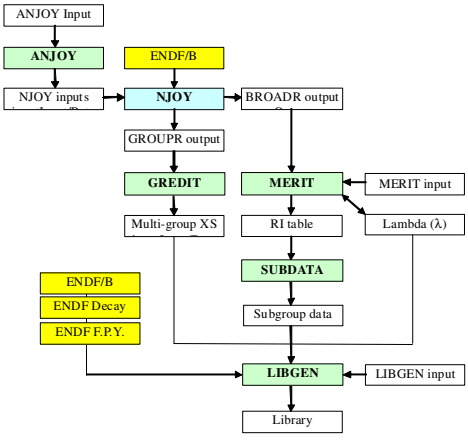

Fig. 1. Programs and procedure for KARMA multi-group library generation

REFERENCES

[1]. S. G. Hong, "Software Verification and Validation Report (ANJOY1.0)," NCD-CA-SVVR-011(r0), 2008/01/11.
[2] R. E. MacFarlane and D. W. Muir, "The NJOY Nuclear Data Processing System, Version 91," LA-12740-M, LANL, 1994.
[3] S. G. Hong, "Software Verification and Validation Report (GREDIT1.0)," NCD-CA-SVVR-013(r0), 2008/01/25.
[4] S. G. Hong, "Software Verification and Validation Report (MERIT1.0)," NCD-CA-SVVR-013(r0), (to be published).
[5] HELIOS Methods, Studsvik Scandpower, 20 November 2003.
[6] K. S. Kim, "Software Verification and Validation Report (SUBDAT1.0)," NCD-CA-SVVR-015(r0), (to be published).
[7] K. S. Kim, "Software Verification and Validation Report (LIBGEN1.0)," NCD-CA-SVVR-016(r0), (to be published).
[8] HELIOS Methods, Studsvik Scandpower, 20 November 2003.

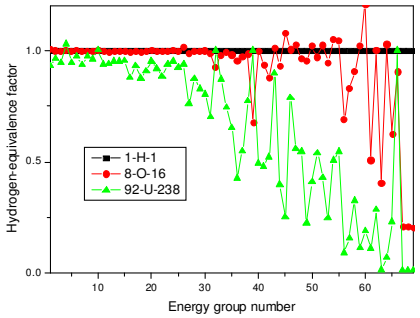

Fig. 2. Comparison of the hydrogen-equivalence factors

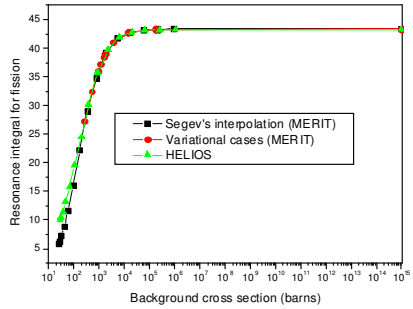

Fig. 3. Comparison of the resonance integrals versus background cross section
(U-235 fission, T=700K, 60th group)

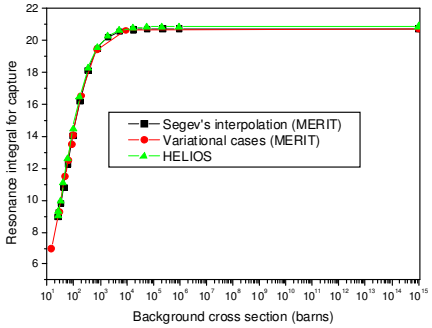

Fig. 4. Comparison of the resonance integrals versus background cross section
(U-238 capture, T=700K, 60th group)