A Validation Test of ORIGEN2/HELIOS for AMBIDEXTER Design Studies

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1. Introduction

The ORIGEN2–HELIOS–AMBIKIN2D code system, shown in Fig. 1 has been developed for AMBIDEXTER design studies[1]. The procedures adapted are as follows; nuclide compositions and group constants for the molten-salt reactor core are recursively calculated by the ORIGEN2 and HELIOS [2] coupling; and the results are used for AMBIKIN2D core calculations. HELIOS herein is used to generate not only group constants for AMBIKIN2D but also library for ORIGEN2.

This study is aiming at investigating the feasibility of the ORIGEN2-HELIOS coupling for this framework, using MCNP5 [3].

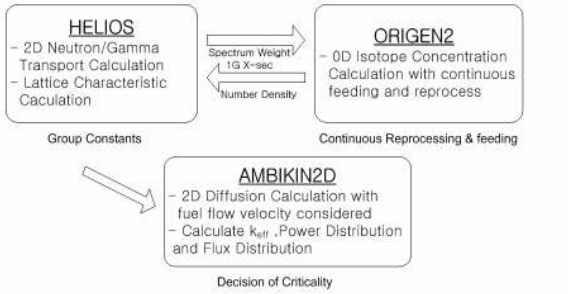

Fig. 1. Code System of AMBIDEXTER

2. Simulation Model

The reactor model for tests was the AMBIDEXTER loaded with NaF-ZrF_4-(R-DUPIC)F_x, where R-DUPIC stands for uranium-reduced DUPIC fuel. Its nuclides composition was estimated with ORIGEN2 for PWR spent fuel at typical discharge burn-up.

As shown in Fig. 2, the reactor core consists of seed lattices to provide thermal neutron environment for dominantly producing fission energy and neutrons, and of centrally down-coming blanket zone having the advantage of transmuting TRU isotopes to fissile. But this study dealt only with the seed lattice in the form of a hexagonal cylinder with 10cm flat-to-flat distance and a 1.5cm dia. circular flow channel at center.

3. Method and Result

For investigating the validity of HELIOS applications to conceptual design of AMBIDEXTER-type reactors, we started with the sensitivity of the library group structure on the neutron multiplication by comparing HELIOS results with MCNP5's. Then analyzed the individual nuclide effects on k_∞.

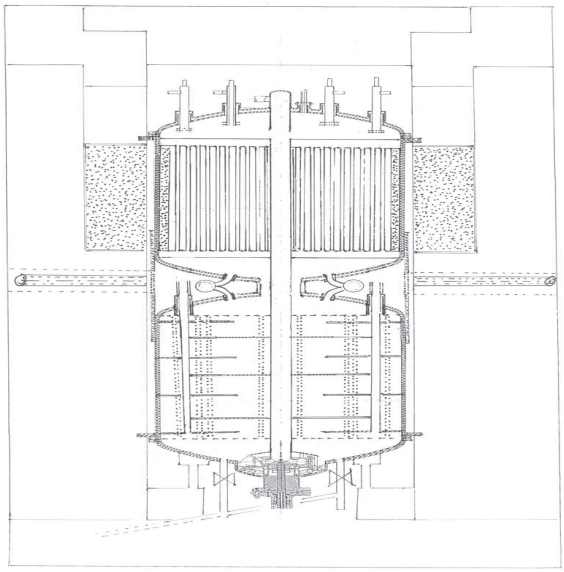

Fig. 2. AMBIDEXTER Reactor System

3.1 Global Effect

Both of the ENDF/B-VI and –VII libraries for the same operating temperature was generated using the NJOY99.161 processing code[4].

The HELIOS simulations were performed with 89 and 190 group libraries, based on ENDF/B-VI. And corresponding MCNP5 simulations were with ENDF/B-VI and -VII. Calculated k_∞'s of the cases are given in Table I, from which it can be said that, for the HELIOS library, the fine group structure is more appropriate for the design study than the coarse one. But because of discrepancy between MCNP library cases, it is need to be confirmed by individual nuclide's contribution.

Table I. k_∞ of HELIOS and MCNP5

	k_∞
HELIOS 89-group	1.12374
HELIOS 190-group	1.13075
MCNP5 ENDF/B-VI	1.12877±0.71
MCNP5 ENDF/B-VII	1.12624±0.73

3.2 Nuclides Effects

In spite of reasonable accuracies for feasibility study with maximum 5.5 mk for k_∞ predictions as above, it is worthwhile to investigate the source of discrepancies.

Table II summarizes differences in 2-group microscopic absorption cross-sections of important nuclides between MCNP-with-ENDF/B-VI and MCNP-with-ENDF/B-VII calculations.

Table II. Difference of 2-group cross section of nuclides

	thermal	Fast
Zr90	-85.56%	5.34%
U235	0.02%	0.08%
U238	1.44%	1.10%
Pu239	0.08%	-0.11%
Pu240	0.05%	-0.18%
Pu241	-1.30%	0.30%
Pu242	0.02%	0.38%

The table shows that ENDF/B-VI over-predicts neutron absorption by U-238 over the entire energy range, that should be the main source of k_∞ difference in MCNP calculations.

On the other hand, the table shows that the difference of Zr-90's thermal absorption cross sections between ENDF/B-VI and ENDF/B-VII is reversely directed to that of its fast neutron group data. According to Fig. 3, these differences should be the principal reason why the large k_∞ error exists between HELIOS predictions with 89 group and 190 group libraries.

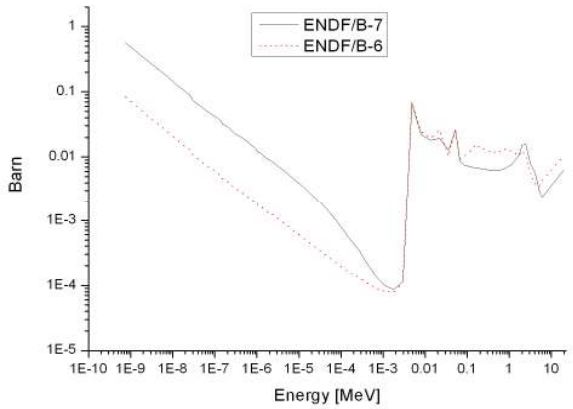

Fig. 3. Absorption cross section of Zr-90

4. Conclusion and Discussion

The ORIGEN2 and HELIOS coupling has been used for conceptual design studies of the AMBIDEXTER. In order to examine the validity of the code coupling for the purpose, an MCNP5 model with ENDF/B-VI and -VII for its seed lattice was simulated and compared with the HELIOS models with 89 and 190 energy group libraries.

With present results, it can be said that HELIOS predictions of k_∞ are in good agreement with MCNP5 with maximum discrepancy of 5.5 mk, but it should be better with finer group structure. Also in order to improve the prediction accuracy, the ENDF/B-VI based HELIOS library should be replaced by the ENDF/B-VII based one. Major improvement would be expected due to U-238 data.

Because Zr is an important nuclide in the fuel salt composition, the validity of HELIOS for the neutronics of the AMBIDEXTER-type reactors would be strongly affected by the reliability of its nuclear data basis. And, although the integral effect on k_∞ prediction would be small, the sensitivity of the code validity on neutron spectrum should be carefully examined. This will be also improved when use the ENDF/B-VII library.

Therefore, to ensure the validity of the ORIGEN2 and HELIOS coupling method for the AMBIDEXTER design studies, HELIOS library improvement should be one of key tasks. To confirm this, extended MCNP calculations with ENDF/B-VI and ENDF/B-VII based libraries are required. These include assessing the effect of concentration changes in important nuclides, such as Zr isotopes, principal FPs, and isotopes of Pu and minor actinides.

Reference

[1] S.K. Oh, Y. J. Lee, T.K. Ham, M.H. Seo, Designed and Operational Characteristics of the AMBIDEXTER-NEC with Uranium-Reduced DUPIC Fuel Material, ICAPP, 2007
[2] HELIOS user's manual
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[4] R. E. McFarlane, D. W. Muir, "The NJOY Nuclear Data Processing System Version 91", LA-12740-M (1994)