Preliminary Development of SFR Nuclear Code System for Regulatory Evaluation

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1. Introduction

Fast reactors such as PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor) developed by KAERI have fundamental differences in terms of core characteristics and associated fuel cycle compared to thermal reactors, which need specific new effort for nuclear evaluation. The SFR nuclear code system for regulatory evaluation has an object to verify core integral parameters, and reactivity coefficients, etc. provided by the designers and generate reactivity coefficients and kinetic parameters for safety analyses.

For these purpose, both stochastic (Monte Carlo) and deterministic tools can be used. In the deterministic regulatory code system, the EXUS-F code [1] to process evaluated nuclear data into ultrafine or fine group cross section libraries and generate multigroup cross sections have been developed by Seoul Nation University (SNU). The PARCS code [2] is considered for the whole-core diffusion calculation, and the nTRACER-F code based on the MOC method has been developing for the whole-core transport calculation by SNU.

This paper presents the current development status of SFR nuclear code system for regulatory evaluation and the preliminary core analysis results calculated using the EXUS-F/PARCS code system.

2. Current Development Status of SFR Nuclear Code System for Regulatory Evaluation

The objective of SFR nuclear evaluation system for regulatory verification is as follows:

(a) verification of core integral parameters, reactivity coefficients, and power peaking factor, etc. provided by the designers,
(b) generation of reactivity coefficients and kinetic parameters for safety analyses based on point-kinetics calculation, and
(c) implementation of the space-dependent neutron dynamics analyses for neutronics coupled thermal-fluid calculation

For these purpose, both deterministic and Monte Carlo tools have been considered.

The SFR nuclear evaluation code system is shown in Fig 1. In the deterministic regulatory code system, the EXUS-F [1] to process evaluated nuclear data into ultrafine or fine group cross section libraries and generate multi-group cross sections has been developed by SNU. In EXUS-F, the capability for that the cross section preparation and 0-dimensional ultrafine group spectrum calculation was confirmed. The extension of EXUS-F to one/two-dimensional problems using the MOC solver with anisotropic scattering is underway.

For the whole-core diffusion and transient calculation, PARCS [2] is used and the hexagonal core analysis capability of PARCS has been evaluating with various problems. For multigroup whole-core transport calculation, nTRACER-F based on nTRACER [3] has been developing by SNU.

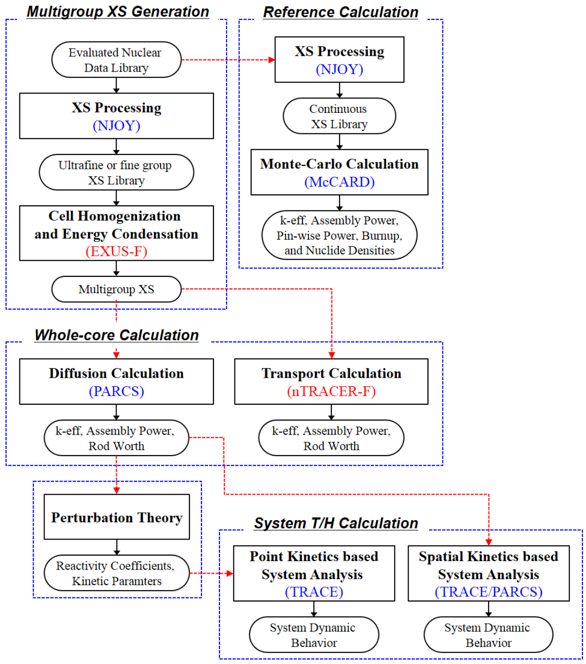

Fig 1. SFR Nuclear Code System for Regulatory Evaluation

3. Verification of the EXUS-F/PARCS Code System for Homogeneous Problems

In order to verify the calculation capability of the EXUS-F/PARCS code system in the view of regulatory review, BFS-73-1 benchmark problem [4] and TRU-300 problem [5] were analysed for the homogeneous problems. The verification of the EXUS-F/nTRACER-F code system will be carried out after preliminary development of nTRACER-F.

3.1 BFS-73-1 Benchmark Problem

The BFS-73-1 critical experiment was mounted in the BFS-1 critical facility to examine the KALIMER core loading metallic uranium fuels [4]. In order to implement the whole-core calculation using PARCS, the group constants for various energy groups such as 2G, 4G, 10G, 34G, and 71G were generated by EXUS-F based on the ENDF/B-VII.0 library. The k-effective calculation results by EXUS-F/PARCS are shown in Table 1. The k-effective using 71G are compared with ones calculated by McCARD and previous K-Core system with TRANSX/TWODANT/DIF3D as shown in Table 2.

The difference of reactivity by the number of energy group is ~150pcm, and the difference between reactivity by EXUS-F/PARCS with 71G and reference is about 414pcm. Additionally, it is noted that the k-eff results by evaluated nuclear data libraries have large error with maximum 1300pcm.

Table 1. k-eff calculation results for BFS-73-1

# of G	2G	4G	10G	34G	71G
k-eff	0.99407	0.99581	0.99634	0.99505	0.99417

Table 2. Comparison of k-eff calculation results for BFS-73-1

Calculation Tools		k-eff	dev.
EXUS-F/PARCS (71G)		0.99417	-
McCARD	JENDL-3.3	0.97908	0.00011
	ENDF/B-VI	0.98883	0.00011
	ENDF/B-VII	0.99207	0.00012
**K-Core System	TWODANT	0.99786	-
	DIF3D	0.99442	-
MMKKENO		0.99870	0.00020
*Reference		0.99830	0.00150

*Calibration of Measured Value
**previous version with TRANSX/TWODANT/DIF3D

3.2 300MWe TRU Burner

The TRU-300 burner was considered as one of SFR demonstration reactor concepts [5]. In the TRU-300 core, fuel assemblies with transuranic isotopes are loaded. The same energy group structures as the BFS-73-1 problem with 2G, 4G, 10G, 34G, and 71G were used in this problem. The k-effective calculation results by EXUS-F/PARCS are shown in Table 3. The k-effective using 71G are compared with ones calculated by McCARD and K-Core system as shown in Table 4.

Table 3. k-eff calculation results for TRU-300

# of G	2G	4G	10G	34G	71G
k-eff	1.03554	1.03999	1.05300	1.05684	1.05616

Table 4. Comparison of k-eff calculation results for TRU-300

Calculation Tools		k-eff	dev.
EXUS-F/PARCS (71G)		1.05616	-
McCARD	JENDL-3.3	1.04449	0.00016
	ENDF/B-VI	1.05898	0.00017
	ENDF/B-VII	1.04972	0.00016
*K-Core System	DIF3D	1.05483	-
	Transport Correction	1.05975	-

*previous version with TRANSX/TWODANT/DIF3D

As shown in Table 3, the k-eff results using 2G and 4G have the large errors in more than 1000pcm. These results mean that the group constants with energy group structure above about 10G are used at least.

The power distributions of the TRU-300 problem were compared as shown in Fig 2.

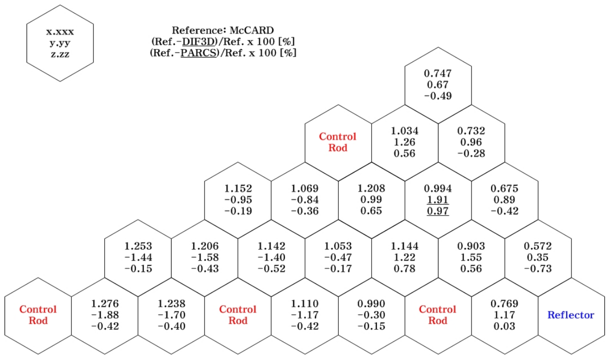

Fig 2. Comparison of assembly power distributions of TRU-300

The maximum power distribution and RMS (root mean square) errors by EXUS-F/PARCS are 0.97% and 0.52% respectively, while the maximum power distribution and RMS errors by previous K-Core system based on DIF3D are 1.91% and 1.22% respectively.

4. Conclusions

In this study, the current development status of SFR nuclear code system for regulatory evaluation was briefly introduced. Currently, (1) the improvement of EXUS-F to one/two-dimensional problems using the MOC solver and (2) the development of nTRACER-F for the hexagonal whole-core transport calculation are underway. For the preliminary core analyses of BFS-73-1 and TRU-300, the EXUS-F/PARCS code system was used. The accuracy of EXUS-F/PARCS was confirmed through comparisons with McCARD and K-Core system. Additional verification and validation of EXUS-F/PARCS and EXUS-F/nTRACER-F will be carried out using various benchmark problems and operation data.

ACKNOWLEDGEMENTS

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