Core Follow Calculation of KARMA/MASTER System for Yonggwang Unit 1

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has developed the transport lattice code called KARMA [1] (Kernel Analyzer by Ray-tracing Method for Fuel Assembly) to be used in the nuclear design for the operating domestic PWRs. This program includes the 47-group and 190-group libraries which are provided by the KAERI library processing system [2].

As a part of code verification and validation for KARMA, core follow calculations of Yonggwang Unit 1 cycles 1 through 7 were performed and detailed comparisons were done via statistical analysis of the differences between calculation results and measured data.

2. Methods and Results

2.1 Libraries and Code Packages

In this work two kinds of the library are applied. Both are processed from ENDF/B-VII R0 but differ in treatment of fission products. Since KARMA code and the library are closely intertwined, two different versions of KARMA code, 1.1 Mod 1 and 1.1 Mod 2, has been released respectively. KARMA 1.1 Mod 2 library additionally treats the following fission products as resonance nuclides; 47-Ag-109, 60-Nd-145, 61-Pm-147, 62-Sm-152, 62-Sm-147, 63-Eu-153.

Homogenized group constants generated by KARMA are fed into PROLOG [3] and converted to the group constant tablesets and the heterogeneous formfunctions. MASTER [4], which is a nuclear design code based on the two group diffusion theory, takes these libraries to calculate the steady state and transient behavior of reactor core.

2.2 Comparisons

Comparisons were performed with plant measurement data from Yonggwang Unit 1 cycles 1 through 7. These include safety related parameters such as reactivity, power distribution, temperature coefficient, inverse boron worth and control bank worth. Results of CASMO-3/MASTER [5] also are introduced as reference calculation.

2.3 Results

Fig. 1 shows reactivity differences between measured data and calculated data. The reactivity differences were estimated by the difference of the HFP critical boron concentration multiplied by boron worth which is calculated at each burnup step. KARMA 1.1 Mod 1 is very consistent with reference calculation. However, KARMA 1.1 Mod 2 relatively underestimates reactivity. This is mainly due to the critical boron concentration predictive capabilities of KARMA 1.1 Mod 2, as shown in Fig. 2. Maximum difference is 383.2 pcm for KARMA 1.1 Mod 1 and 577.0 for KARMA 1.1 Mod 2 in comparison with the measured data.

Table I describes the cycle-wise maximum root mean square errors of assembly radial power distribution. Comparisons were performed at least one data point per 30 EFPD for each cycle, if available. All predictions are within the typical criteria of ±5 % in root mean square error.

Differences between calculated and measured values in isothermal temperature coefficients are shown in Fig. 3. For KARMA 1.1 Mod 1, maximum difference is less than 1 pcm/℃. Meanwhile the result of KARMA 1.1 Mod 2 is shifted lower to the interval [-1.60, -0.07] in the unit of pcm/℃.

Fig. 4 illustrates individual bank worth differences. Maximum difference is 17.0% for KARMA 1.1 Mod 1 and 20.9% for KARMA 1.1 Mod 2. The results of KARMA calculation generally fit well with the results of CASMO-3, though KARMA has relatively large deviation, especially when bank worth is small.

Inverse boron worth differences are shown in Fig. 5. It can be seen that KARMA and CASMO-3 are in close agreement with each other. All the results are under 12% limit which is tolerance limit of CASMO-3 for safety analysis.

3. Conclusions

Core follow calculation of Yonggwang Unit 1 has been performed. Overall results show that the predictive capabilities of KARMA can be generally accepted.

In addition, this work will be followed by uncertainty evaluation calculation to set tolerance limits on certain confidence level.

REFERENCES

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[4] Jin-young Cho, *et al.*, "MASTER 3.0 User's Manual", KAERI/UM-8/2004, 2004.

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Table I: Cycle Maximum Root Mean Square Errors of Assembly Radial Power Distriburions

Cycle	Number of Comparison	Max (RMS)		
		Mod 1	Mod 2	CASMO-3
1	221	2.89%	2.90%	1.75%
2	438	4.04%	4.36%	1.79%
3	377	3.38%	3.77%	2.21%
5	324	2.44%	2.83%	1.94%
6	339	2.19%	2.23%	1.88%
7	414	1.92%	2.17%	1.19%

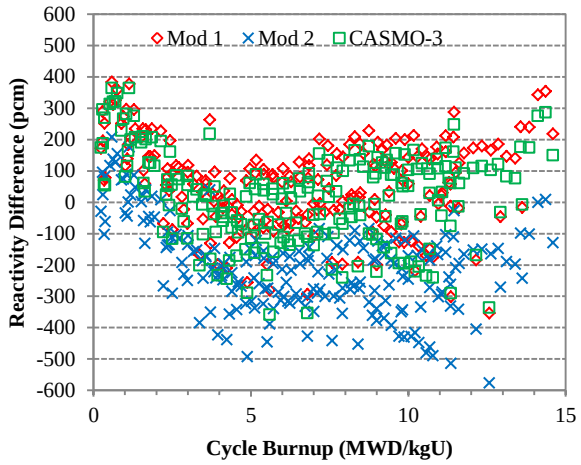

Fig. 1. Reactivity Differences

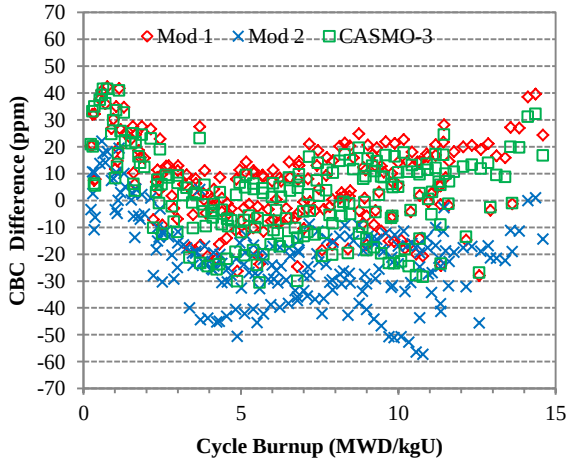

Fig. 2. Critical Boron Concentration Differences

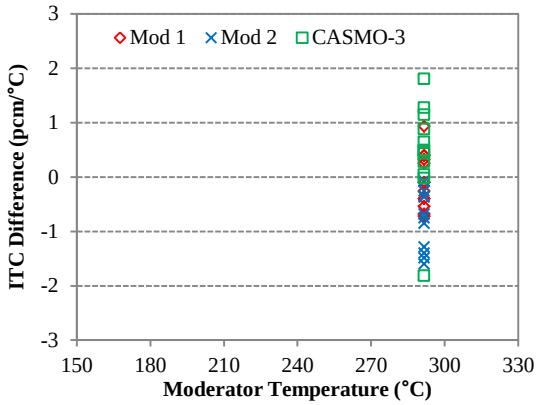

Fig. 3. Isothermal Temperature Coefficient Differences

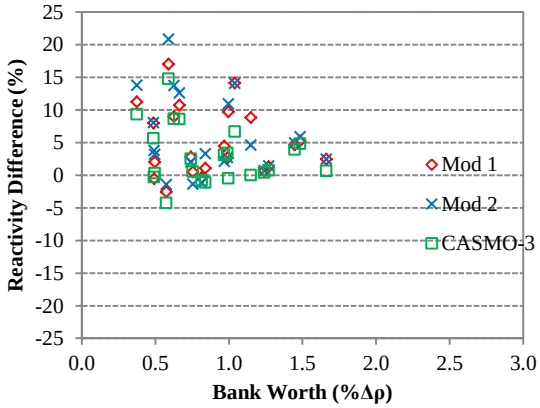

Fig. 4. Individual Bank Worth % Differences

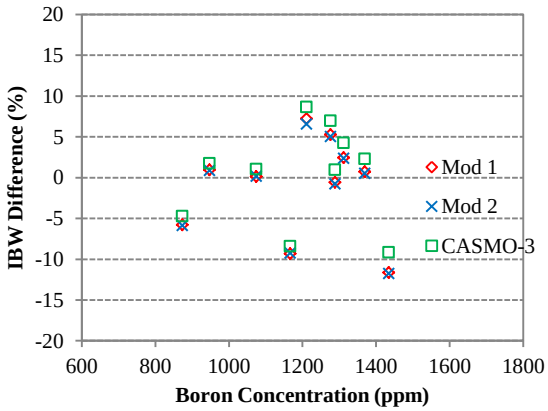

Fig. 5. Inverse Boron Worth % Differences