Application of CASMO-3/MASTER Code System to the OPR1000

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1. Introduction

MASTER[1](Multi-purpose Analyzer for Static and Transient Effects of Reactors), which was developed by KAERI, is the nuclear design code having the capability of static core design, transient core analysis and operational support. And CASMO-3[2], which is a fuel assembly burnup program, is the lattice calculation code to generate cross sections for core design code.

To validate the core design of APR1400 CASMO-3/MASTER codes have been selected as independent code system. The core design of APR1400, however, is in progress and the final design data and analysis results are not produced. Therefore, OPR1000, which has sufficient information, is selected as a reference plant to demonstrate the performance of CASMO-3/MASTER code package. This demonstration has been performed using design data of UCN #4 Cycle1 and the results are compared to Nuclear Design Report(NDR)[3] of the UCN #4 Cycle 1. The performance of the code package is verified through uncertainty quantification according to the uncertainty evaluation report written by KAERI.

2. Core Design and Analysis Procedures

2.1 Core Description

The reactor core is composed of 177 fuel assemblies. The fuel assemblies are arranged to approximate a right circular cylinder with an equivalent diameter of 312.4cm and an active fuel length of 381cm. Each fuel assembly, which consists of a 16x16 array of 236 fuel rods and 5 guide tubes welded to spacer grids, is closed at the top and bottom by end fittings. The guide tubes each displace four fuel rod positions and provide channels which guide the CEAs over their entire length of travel. Incore instruments are installed in the central guide tubes of selected fuel assemblies. Fuel rods are composed of 1.8~3.34 w/o of UO_2 pellet and Zircaloy-4 cladding. The fuel assembly has normal fuel and gadolinia fuel rod. The former is composed of all UO_2 fuel region. The latter is made up of cutback region which is located in both ends and Gd fuel region which is the mixture of 2 w/o U_{235} and 4, 8 w/o gadolinia.

2.2 Calculation Process

UCN #4 Cycle 1 core is composed of 9 kinds of fuel assemblies. Among them, 5 fuel assemblies, which has gadolinia burnable absorbers, has cutback region. Therefore, actually 14 cross section data are generated by CASMO-3 code.

MASTER code is used for the core analysis of UCN #4 Cycle 1 with 14 cross sections obtained in CASMO-3 code and generates boron concentration, temperature coefficients, control rod worth and so on. Then, such the results as nuclear design parameters are compared to NDR of the UCN #4 Cycle 1. The difference is compared to uncertainty quantification of CASMO-3/MASTER code system. The nuclear design parameters of uncertainty evaluation report[4], which was written by KAERI, are below.

Table 1. The Uncertainty of Nuclear Design Parameter in CASMO-3/MASTER code system

Nuclear Design Parameter	Uncertainty
Reactivity	410pcm
Power peaking factors(Fxy, Fr, Fq)	0.05-0.07
Isothermal temperature Coefficient	2.5pcm/℃
Moderator temperature Coefficient	2.5pcm/℃
Individual rod worth	15%
Accumulated rod worth	10%
Inverse boron worth	12%

3. Results

Critical Boron Concentration(CBC) is important nuclear design parameter in burnup calculation and actual plant operation because the CBC is compared to plant measuring data and it is related with a bias. Figure 1 shows that the CBC difference between the NDR of UCN #4 Cycle 1 and the results by CASMO-3/MASTER code system is less than 50ppm. If this difference is transformed into the core reactivity, it is 440pcm and it is within the OPR1000's uncertainty which is within 500pcm.

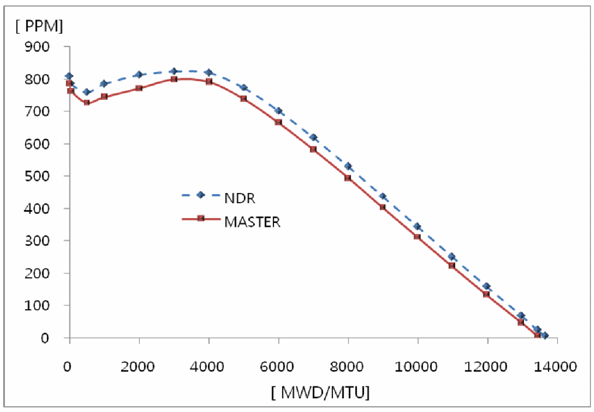

Figure 1. Critical Boron Concentration vs. Burnup

In table 1, such power peaking factors as Fxy, Fr and Fq are between 0.05 and 0.07. However, we cannot compare the data of NDR to the results of CASMO-3/MASTER code system because there is not power peaking factors in NDR. Therefore, we only confirm that the results of CASMO-3/MASTER code system meet the design limits of UCN #4 Cycle 1.

Figure 2 shows the Moderator Temperature Coefficient(MTC) at hot full power and xenon equilibrium. The NDR's method for MTC calculation is different from CASMO-3/MASTER code system. CASMO-3/MASTER code system calculates MTC using automatic option. On the other hand, MTC is calculated using approximated method in NDR. Nevertheless, the maximum difference of MTCs is 2.36 pcm/℃, which is within the uncertainty of CASMO-3/MASTER code system. If we calculate MTC following the NDR's method, the difference is less than 2.36 pcm/℃. The results of Isothermal Temperature Coefficient(ITC) are not shown because the calculated values of ITC are similar to the results of MTC.

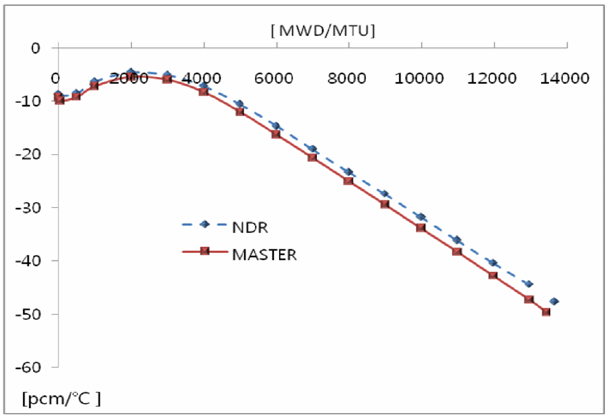

Figure 2. MTC vs. Burnup

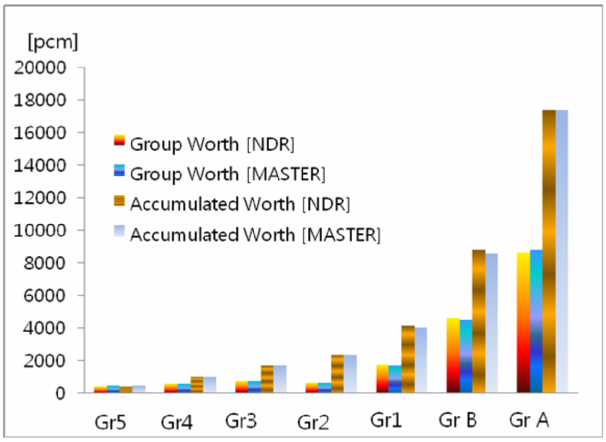

Figure 3. Control rod worth vs. Groups

Figure 3 shows control rod worth in BOC. Both individual and accumulated control rod worth are within uncertainty and almost coincide with the values of NDR. The difference between NDR and CASMO-3/MASTER code system is all within 2.8%. Inverse boron worth is also within uncertainty, which is 12% and below.

4. Conclusions and Further Studies

The results of demonstrating the performance of CASMO-3/MASTER code system are within the uncertainty of the CASMO-3/MASTER code system. These results enable us to use CASMO-3/MASTER code system for the OPR1000 core design and performance evaluation if plant measuring data are much achieved and precise procedure of nuclear design parameter calculation is established.

In the future, we are going to study core transient performance for OPR1000. In detail, the single rod drop tests are able to be conducted by the CASMO-3 /MASTER code system and the results will be compared to the DIT/ROCS code system results.

REFERENCES

[1] "MASTER 3.0 USER'S MANUAL", KAERI, March, 2004.
[2] "CASMO-3 A Fuel Assembly Burnup Program User's Manual", January, 1991.
[3] "Nuclear Design Report for ULCHIN Nuclear Power Plant Unit 4 Cycle 1", June 1999.
[4] "Verification and Uncertainty Evaluation of CASMO-3/MASTER Nuclear Analysis System", KAERI, June, 2000.