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Monte Carlo Benchmark Calculations for 400MW_{th} PBMR Core

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1. Introduction

A large interest in high-temperature gas-cooled reactors (HTGR) has been initiated in connection with hydrogen production in recent years. In this study, as a part of work for establishing Monte Carlo computation system for HTGR core analysis, some benchmark calculations for pebble-type HTGR were carried out using MCNP5 code [1]. As for Korea, the experiences for the commercial reactor of pebble-type to be developed for hydrogen production are poorly accumulated. Therefore, the core of the 400MW_{th} Pebble-bed Modular Reactor (PBMR) was selected as a benchmark model.

Recently, the IAEA CRP5 neutronics and thermal-hydraulics benchmark problem was proposed for the testing of existing methods for HTGRs to analyze the neutronics and thermal-hydraulic behavior for the design and safety evaluations of the PBMR. This study deals with the neutronic benchmark problems, for fresh fuel and cold conditions (Case F-1), and first core loading with given number densities (Case F-2), proposed for PBMR. After the detailed MCNP modeling of the whole facility, benchmark calculations were performed. Results to benchmark problems have been obtained by MCNP5 Code [1].

2. PBMR Modeling with MCNP Code

2.1 Fuel Pebble Modeling

Spherical fuel region of a fuel pebble is divided into cubic lattice element in order to model a fuel pebble which contains, on average, 15000 CFPs (Coated Fuel Particles). Each element contains one CFP at its center. In this study, the side length of each cubic lattice element to have the same amount of fuel was calculated to be 0.1635cm. The remaining volume of each lattice element was filled with graphite. All of different 5 concentric shells of CFP were modeled.

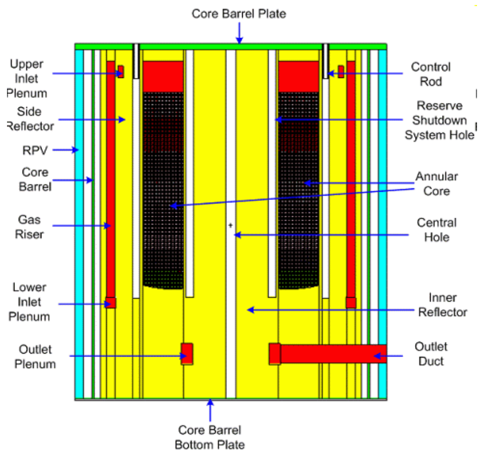
2.2 Core Modeling

The PBMR consists of annular core with an inner radius of 1.0m and an outer radius of 1.85m. The active height of the core is 11.0m. The pebbles gradually move downward in the core bed from top loading locations and exit via one of three de-fueling chutes at the bottom of the bed.

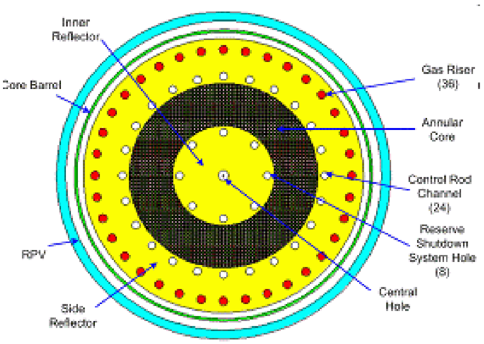
The PBMR annular core consists of approximately 452000 pebbles in the benchmark problems. In Case F-1 where the core was filled with only fresh fuel pebble, a BCC(body-centered-cubic) lattice model was employed in order to achieve the random packing core with the packing fraction of 0.61. The BCC lattice was also employed with the size of the moderator pebble increased in a manner that reproduces the specified F/M ratio of 1:2 while preserving the packing fraction of 0.61 in Case F-2.

2.3 Whole Facility Modeling

The major components of the reactor were also modeled, which are 24 reactivity control systems (RCS), 8 reserve shutdown systems (RSS), 3 de-fueling chutes, 36 gas risers, 2 inlet ducts, outlet duct, 2 inlet plenum, outlet plenum, and reflectors as well as the core. Whole facility modeling was shown in Figure 1.



a) Vertical View



b) Horizontal View

Figure 1. MCNP Modeling for Whole Facility

3. Calculation Results and Discussion

The calculations were pursued with ENDF/B-VI cross-section library and used sab2002 S(α, β) thermal cross-section library for graphite material. The results of this study and other research groups using MCNP4b were represented in Table 1.

Table 1. Calculation Results of Benchmark Problem

	k_{eff}	
	Case F-1	Case F-2
MCNP4b (Turky)	1.27808	1.15329
MCNP5 (This Study)	1.27949±0.00052	1.14014±0.00055

The resulting k_{eff} was calculated to be 1.27949±0.00052 and 1.14014±0.00055 for Case F-1 and F-2, respectively. Comparing with other previous results from MCNP4b code, these results gave an agreement of k_{eff} difference by 141 pcm and 1315 pcm for Case F-1 and F-2, respectively. These results were caused by a different geometry modeled. While 3 bottom cone regions and de-fueling chutes were modeled explicitly in this study, these were assumed to the surfaces flattened in MCNP4b calculations.

4. Conclusion

In this study, some Monte Carlo benchmark calculations were carried out for the PBMR with MCNP5 code. This calculation deals with the neutronic benchmark problems, for fresh fuel and cold conditions, and first core loading with given number densities, proposed for PBMR

It was found that the resulting k_{eff} was different with the result from other research group using MCNP4b, because a geometry modeled was different each other.

This study can be contributed and utilized directly in the establishment of benchmark problems to develop deterministic neutronics analysis tools and methods, which lagged behind the state of the art compared to other reactor technologies, to design and analyze PBMR. It is also expected that this study would be utilized in the validation of a deterministic computer code for HTGR core analysis which will be developed in near future in Korea.

Acknowledgment

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REFERENCES

[1] X-5 Monte Carlo Team, "MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume II: User's Guide," LA-CP-03-0245, Los Alamos National Laboratory (2003).