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Whole Core Analysis Using OpenMC Monte Carlo Code

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1. Introduction

With the development of the parallel computing performance, it has been possible to simulate large scale neutron transport with the Monte Carlo method. The Computational Reactor Physics Group (CRPG) of Massachusetts Institute of Technology (MIT) has opened the OpenMC Monte Carlo code to public, which is capable of calculating a criticality of a core region of the Pressurized Water Reactor (PWR) [1]. The whole core analysis needs high fidelity and accurate modeling of the practical PWR in 3D. In order to check a performance of the OpenMC, the PWR benchmark problem which is called BEAVRS was proposed by Dr. Kord Smith. This paper solves the BEAVRS benchmark problem using the OpenMC code.

2. Specifications

2.1 BEAVRS benchmark

The BEAVRS benchmark problem covers the PWR whole core model with little assumptions. It consists of core support components and 193 fuel assemblies with 264 fuel rods, 24 guide tubes, 1 instrument tube, and 8 grid spacers [2]. The overall radial and axial geometries are shown in Figs. 1 and 2, respectively.

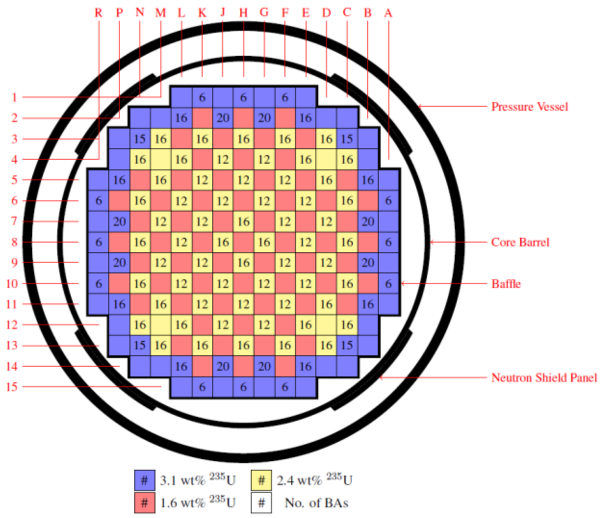

Fig. 1. Schematic layout of core structures and fuel assemblies showing enrichment loading pattern and burnable absorber positions.

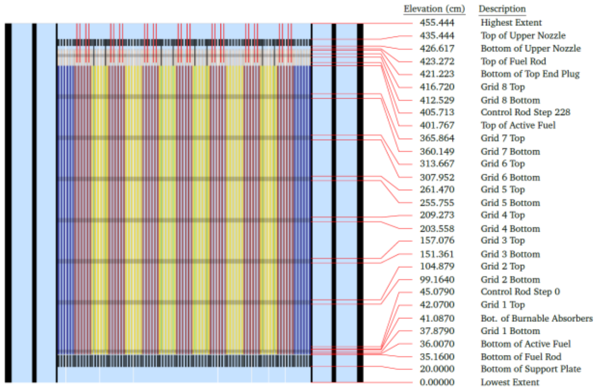

Fig. 2. Scale view of core axial cross-section.

2.2 OpenMC

The OpenMC is a Monte Carlo neutron transport code focused on neutron criticality calculations. It is capable of simulating steady state, three dimensional models. The particle interaction data is based on ACE format cross sections used in the MCNP Monte Carlo code such as ENDF format. Since it only simulates the models of steady state, it is not yet possible to calculate the fuel burn-ups or power history.

3. Measurements and Results

The neutron criticality, k_{eff}, is calculated with 800 batches of 500 thousand particles each with 500 inactive batches. All the control Rods are Out (ARO) and the boron concentration is 975 ppm. The computational time to simulate took 12 hours with 216 processors. The result is shown in Table I, compared with M&C result [2].

The neutron flux of the fuel assembly at the center of the core in axial direction is tallied. It is compared with the detector signals of commercialized PWR at different positions. The result is shown in Figs. 3 and 4.

Table I: Results from OpenMC for HZP ARO condition

	Tallied k_{eff}	σ	Boron Concentration
ARO	1.01822	±0.00006	975 ppm
[2]	1.00088	±0.00006	975 ppm

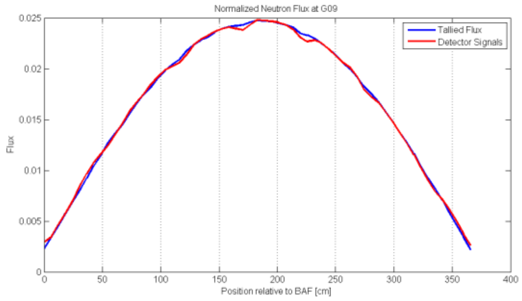

Fig. 3. Flux distribution along axial direction, relative to the bottom of active fuel at G09.

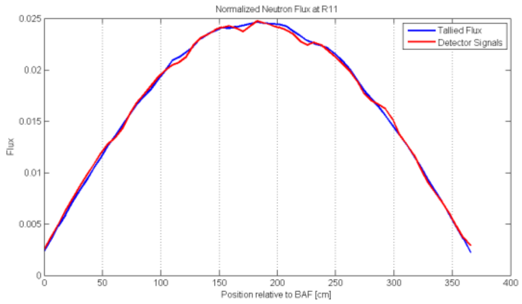

Fig. 4. Flux distribution along axial direction, relative to the bottom of active fuel at R11.

4. Conclusions

The BEAVRS benchmark problem was introduced for high fidelity PWR core with the detail components in 3D. The neutron criticality and the axial flux distribution were obtained in a steady state, ARO condition using OpenMC code.

ACKNOWLEDGEMENTS

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REFERENCES

[1] P. K. Romano, B. R. Herman, N. E. Horelik, B. Forget, and Kord Smith, Progress and Status of the OpenMC Monte Carlo Code, International Conference on Mathematics and Computational Methods Applied to Nuclear Science & Engineering (M&C 2013), Sun Valley, Idaho, USA, May 5-9, 2013.

[2] N. Horelik, B. Herman, B. Forget, and K. Smith, Benchmark for Evaluation and Validation of Reactor Simulations (BEAVRS), v1.0.1. Proc. Int. Conf. Mathematics and Computational Methods Applied to Nuc. Sci. & Eng., Sun Valley, Idaho, 2013.