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Preliminary Solution of BEAVRS Hot Full Power at BOC by Monte Carlo Code

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1. Introduction

This paper presents the preliminary result of BEAVRS Hot Full Power (HFP) solution at Beginning of Cycle (BOC). It is solved by in-house Monte Carlo code which is being developed at Ulsan National Institute of Science and Technology (UNIST) [1-2]. The code employs simple 1-dimentional Thermal Hydraulic (TH) module and multipole based On-The-Fly (OTF) cross section generation module. In this paper, fission reaction rate, fuel temperature, moderator density, moderator temperature, fuel temperature, and xenon number density distributions are presented.

2. Methods and Results

2.1 TH Coupling

The 1-dimentional TH module has been implemented [3]. It receives the power distribution in the fuel pin from MC code. This module updates the coolant condition with the boundary condition of incoming coolant temperature and flow rate. After that, it updates the fuel temperature with fixed coolant temperature determined previous step. TH module sends the temperature and density profile to the MC. The pressure is fixed to 15.5 MPa. The geometry of TH module is pincell which means it does not consider the cross flow through pin.

2.2 Temperature Dependent Cross Section

The OpenW module developed by MIT CRPG has been implemented [4-5]. The OpenW module is On-The-Fly Cross section generation module based on the multipole method. MIT CRPG provides the multipole library for 72 nuclides. The nuclides which is not in the library list can be treated with SIGMA1 kernel. SIGMA1 kernel generate the ACE format file before transport calculation [6-7].

2.3 Equilibrium Xenon

Xenon number density in the fuel changes depending on the power. The xenon effect is negligible if the reactor is in HZP condition since the xenon number density to very small. However, the Xenon number density should be properly considered if it is in Hot Full Power (HFP). To calculate the Xenon number density with given power, Xenon update subroutine has been implemented [8-9]. The MC tallies the fission reaction rate and absorption reaction rate of xenon, and updates the xenon number density according to the following equation

$$N_{Xe} = \frac{\gamma_{Xe} \Sigma_f \phi}{\lambda_{Xe} + \sigma_{Xe,a} \phi} \;, \qquad (1)$$

where γ_{Xe} is the cumulative fission yield of Xe-135, Σ_f is the macroscopic fission cross section, ϕ is the flux, λ_{Xe} is the decay constant of Xe-135, and $\sigma_{Xe,a}$ is the microscopic absorption cross section of Xe-135.

3. Results

3.1 BEAVRS Benchmark

BEAVRS (Benchmark for Evaluation and Validation of Reactor Simulation) was published by MIT [10-11]. It is PWR benchmark contains very detailed information. The conditions used to simulate HFP is in Table I.

Table I: Problem Description

Core power	3,411 MW
Inlet coolant temperature	560 °F
Pressure	2,250 psia
Core flow rate	61.5×10^6 kg/hr
Boron concentration	975 ppm
Control rod position	ARO

3.2 Simulation Result

BEAVRS core is composed of 50,952 number of fuel pins. In the MC code, fuel pin is divided into 60 equal volume meshes (3 radial meshes and 20 axial meshes). In the TH module, fuel pin is composed of 10 radial meshes and 20 axial meshes.

The simulation was performed on Linux cluster with 24 processes (i7 4790K @ 4.00 GHz). Total 345 million histories were used with 900 inactive cycles, 6,000 active cycles, and 50,000 histories per cycle. TH feedback and xenon update subroutine was performed every 300 cycles.

Table II shows the multiplication factor, memory per process and the simulation time.

Table II: Summary of Result

k_{eff}	0.96089
SD	0.00002
Memory per process	~ 50GB
Simulation time	616 mins
# of processes	24

Figs 1-5 show the distribution of five different quantities: flux, fission reaction rate, fuel temperature, moderator density, moderator temperature.

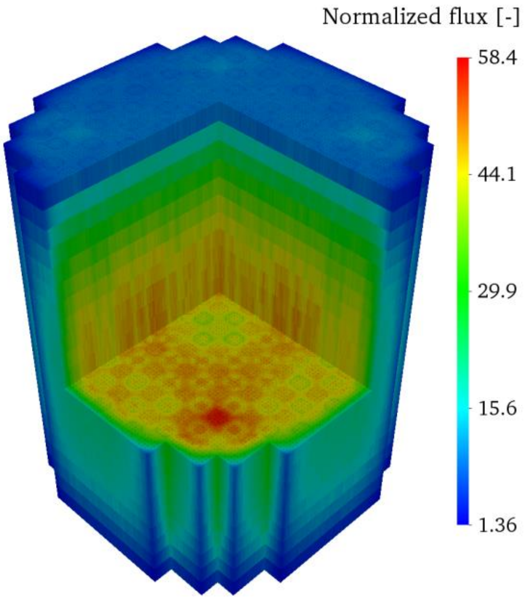

Fig. 1. Flux distribution.

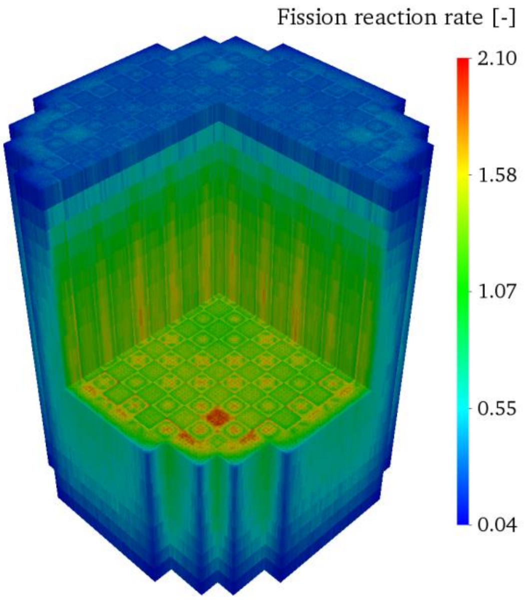

Fig. 2. Fission distribution.

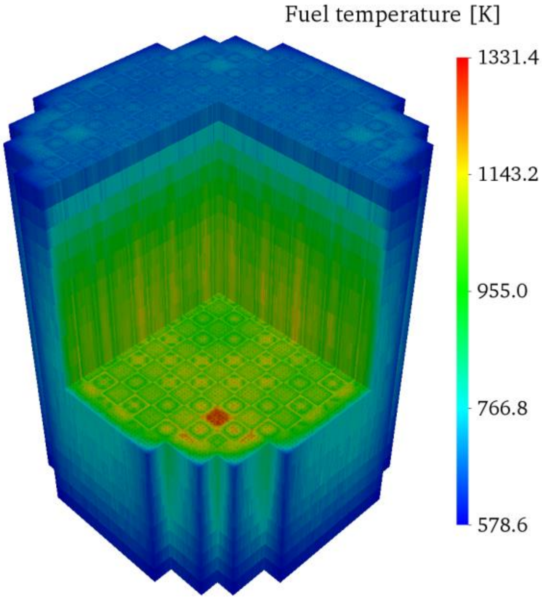

Fig. 3. Fuel temperature distribution.

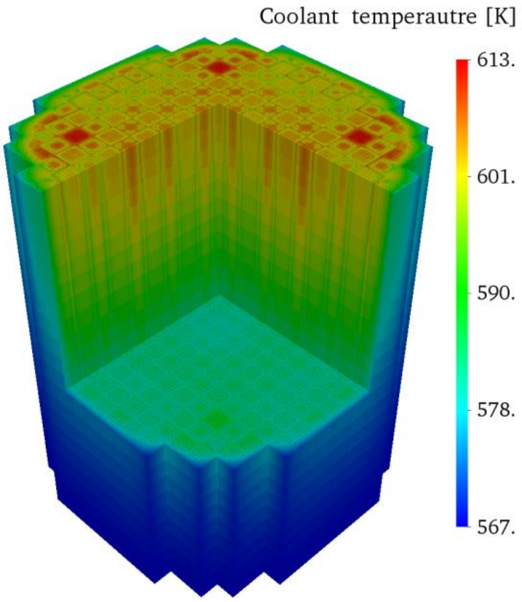

Fig. 4. Coolant temperature distribution.

Figs. 6-7 show the pin averaged xenon number density distribution and one group microscopic absorption cross section of Xe-135. The grin colored region in Fig. 6 contains burnable absorber (BA). Therefore, the microscopic absorption cross section of Xe-135 is smaller because of the spectrum hardening and the number density of Xe-135 is larger. Fig. 8 shows the spectrum in two assemblies positioned at (7,2) and (7,3). The assembly at (7,2) contains 3.1% enriched fuel and 20 BA rod, and the assembly at (7,3) contains 1.6% fuel and no BA rod.

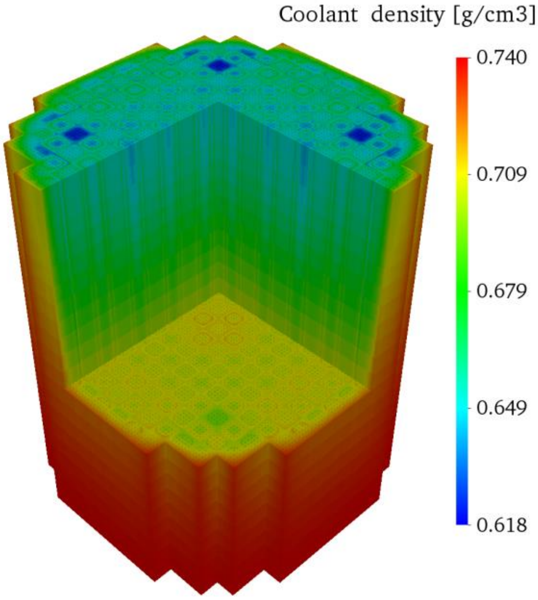

Fig. 5. Coolant density distribution.

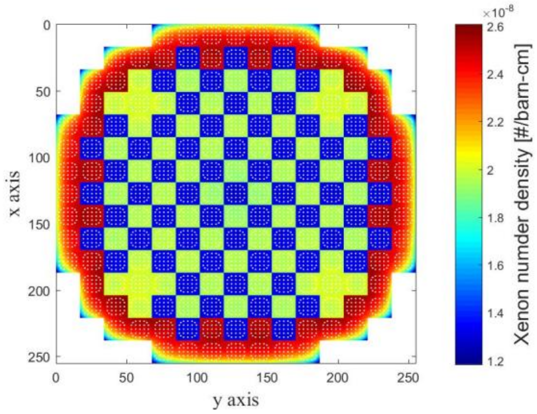

Fig. 6. Pin-wise xenon number density.

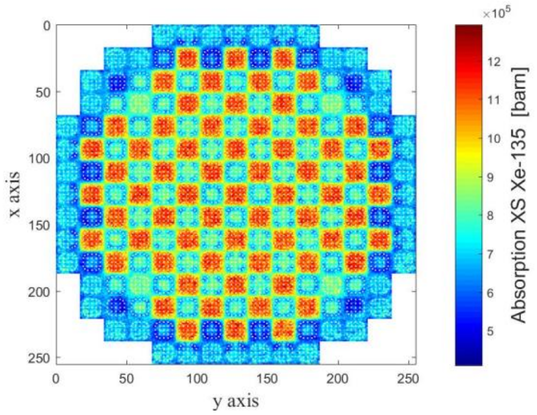

Fig. 7. One group microscopic absorption cross section of Xe-135.

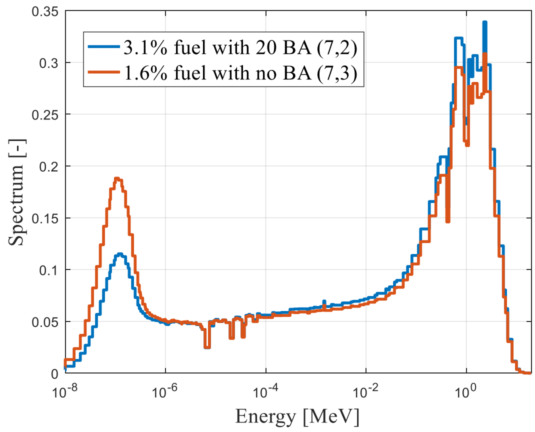

Fig. 8. Integrated spectrum in assembly at (7,2) and (7,3).

3. Conclusions

This paper presented preliminary solution of BEAVRS HFP state at BOC by Monte Carlo code which is being developed at UNIST. The five quantities were presented and all looks reasonable: Fission reaction rate, fuel temperature, xenon number density, moderator density, moderator temperature. The next task would be the verification work. And the BEAVERS HFP depletion calculation will be studied.

ACKNOWLEDGEMENTS

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