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An Evaluation on the Influence of Axial Reflector Thickness into the Fission Source Convergence in MC Eigenvalue Calculation of VHTR Prismatic Reactor

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1. Introduction

Convergence of a fission source distribution in Monte Carlo calculations has been an issue from the early stage of the method development. For the criticality calculation using Monte Carlo method, the fission source convergence should be considered in order to avoid the calculation bias. Moreover, already converged state, continuous calculation of inactive cycle is not necessary [1]. Especially, prismatic VHTR for generation of high temperature heat has been designed higher effective height than conventional pressurized water reactor. Thus, analyses of the prismatic VHTR with Monte Carlo method suffer from slow fission source convergence [2]. MHTGR-350 is a prismatic VHTR, which has an asymmetric reflector thickness along the axial direction. In this case, fission source distribution also becomes strong asymmetrical distribution according to the asymmetric reactor reflector thickness. Therefore, the converged fission source must be verified to pursue the Monte Carlo simulation of the reactor type. In this study, how the axial reflector thickness affects the fission source convergence was evaluated with changing the prismatic VHTR reflector thickness.

2. Methods

To analyze the relationship between the axial reflector thickness and the fission source convergence, the fission source iteration using MCNP code were performed by changing top and bottom reflector thickness. Also, to analyze the asymmetric reflector cases, the thickness of the top reflector are fixed at 10 cm, and bottom reflector thicknesses were changed. A single assembly of the MHTGR-350 was chosen for the analysis. The axial layout of the MHTGR-350 fuel assembly is given as shown in Fig. 1 [3]. The height of top reflector is 118.94 cm while the height of bottom reflector is 198.25 cm. The fuel assembly, of which height is 793 cm, is stacked with 10 fuel blocks; thus, the axial fuel region is divided into 10 sub-regions. The single fuel assembly has 210 fuel compact holes and 6 lumped burnable poison holes. For the calculation efficiency, it is assumed that the fuel compact and lumped burnable poison holes are homogeneously mixed. It is assumed that the initial fission sources are uniformly distributed in the fuel regions. For the judgment of the fission source convergence, Shannon entropy was calculated by MCNP5 code with the ENDF 7.0 and the endf70sab thermal cross-section libraries [4]. The converged cycle is calculated by using the average of the Shannon entropies for the last half of the active cycles [5].

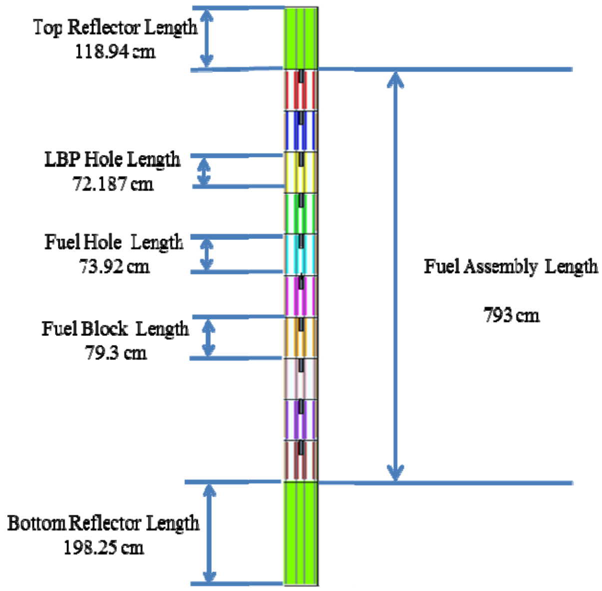

Fig. 1. The MHTGR-350 Fuel Assembly Axial Layout

3. Results

3.1 Fission Source Convergence for the Symmetry Reflector Thickness

To evaluate how the reflector thickness in the symmetric case affects fission convergence cycle, criticality calculations were performed by applying 10 cm, 50 cm, 100 cm, 150 cm, 200 cm, 300 cm, 400 cm, 500 cm, and 600 cm axial reflector thicknesses. Fig. 2 shows the results of the Shannon entropies in each symmetric reflector cases. It is notified that the fission source distributions were slowly converged when the thickness is lower than 200 cm. Fig. 3 is the results of the converged cycle with different reflector thickness. It shows that the converged cycles are continually reduced until 200 cm reflector thickness.

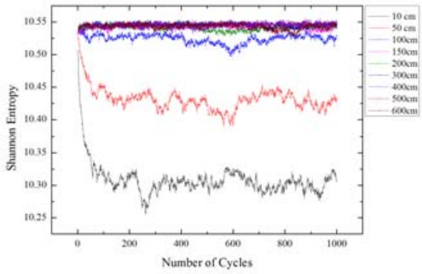

Fig. 2. Results of the Shannon Entropies in Each Symmetric Reflector Cases

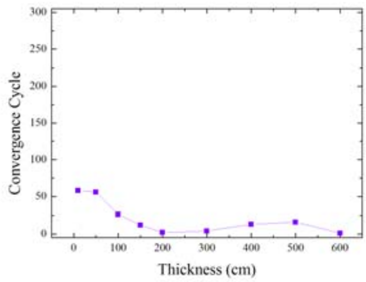

Fig. 3. Results of Convergence Cycle in Each Symmetric Reflector Cases

3.2 Fission Source Convergence for the Asymmetry Reflector Thickness

In the asymmetric reflector thickness, the fission source distributions in the converged cycle also have asymmetric distribution. Hence, the converged cycle from the uniform fission source distribution to the converged distribution is increased. To evaluate how asymmetric reflector affects the fission source convergence, criticality calculations with fixed top reflector thickness were performed by changing the bottom reflector thicknesses from 10 cm to 200 cm. Fig. 4 shows the results of the Shannon entropies in each asymmetric reflector case. The results show that the converged cycles are increased as the difference between top and bottom reflector thicknesses are increased. Fig. 5 shows the results of the convergence cycle in each asymmetric reflector case. The converged cycles are increased to 248th cycle when the thickness difference 200 cm. Analysis shows that the increase of the converged cycle is caused by change of the neutron leakages through the reflectors.

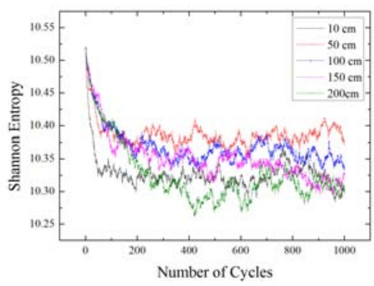

Fig. 4. Results of the Shannon Entropies in Each Asymmetric Reflector Cases

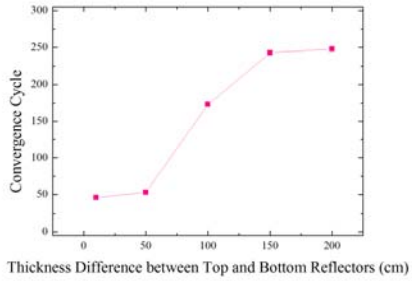

Fig. 5. Results of Convergence Cycle in Each Asymmetric Reflector Cases

4. Conclusions

In this study, how the axial reflector thickness affects the fission source convergence was evaluated. For the symmetric reflector cases, the results show the fission source distribution was converged within 60th cycle. However, in the cases of the asymmetric reflector thickness, it is notified that the convergence cycle of the fission source distribution exceeded 200th cycle. Analysis shows that the inactive cycle for the Monte Carlo eigenvalue calculation should be considerably decided when the reactor has asymmetric reflector thicknesses such as the MHTGR-350. It is expected that these results can be directly used for evaluating and analyzing the prismatic VHTR with Monte Carlo method.

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