Monte Carlo calculation for Modeling HTR-10 core

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1. Introduction

As a part of establishing Monte Carlo computation system for the high temperature gas-cooled reactor (HTGR) core analysis, the benchmark calculations for HTGR is carried out using MCNP code. There are many HTGR reactors, but the core of HTR-10 in China is selected as a reference benchmark model. IAEA already published the benchmark problem sets [1], and this open information plays the guideline to model the HTGR core.

This study models the core through the more accurate approach, and deals with the part of core physics benchmark problems proposed for HTR-10 initial core. The results are obtained by MCNP5 code and the remark point for using executing MCNP is figured out.

2. Method

MCNP (Monte Carlo N Particle transport code) is the 3 dimensional Monte Carlo transport code that can be used for calculations involving coupled neutron/photon/ electron transport [2]. To modeling the core, this code does not solve the neutron transport equation directly, but statistically approaches.

The general design information of HTR-10 was referred to IAEA report [1]. A double-heterogeneous MCNP spherical model was constructed to simulate a core. The first heterogeneity was in TRISO for fuel pebble, and the second heterogeneity was implemented at the reactor core lattice. The individual TRISO coated fuel particles were distributed in the fueled region of the fuel pebbles using a simple-cubic (SC) lattice, and the basic unit of the core lattice was constructed in hexagonal prism (HEX) in this study. In previous studies, the core zone was approximated using a body-centered cubic (BCC) lattice with moderator pebbles of reduced diameter, which reproduces the specified fuel-to moderator pebble ratio, 57:43. The both, BCC and HEX structure are implemented in this study. The double-heterogeneous geometric configurations of the HTR-10 model are shown in Figure 1.

3. Results & Discussions

The result of MCNP simulation is compared with the previous studies for the same conditions in Figure 2. It can be found that Monte Carlo calculations yield slightly higher k_{eff}, though the trend of curves is identical. The results in Figure 2 and Table 1 reflect that MCNP modeling of HTR-10 core seems reasonable.

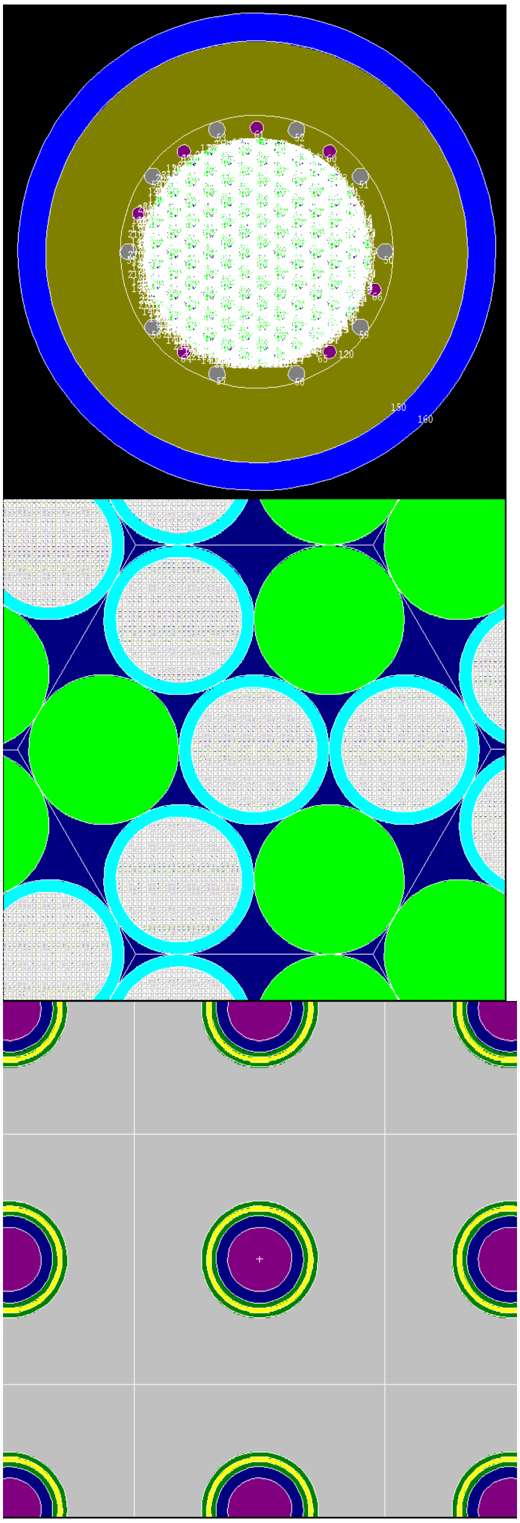

Figure 1. Double heterogeneous **MCNP core modeling (Full core, HEX lattice, TRISO in SC lattice)**

As shown in Table 1 and 2, the results can be different, even using the same approach such as Monte Carlo method. The difference comes from calculation conditions. The version of MCNP may adopt the different random number generation algorithm. It is drawn that the executing conditions affect the output as well. The difference of the multiplication factor mainly came from several factors: the version of MCNP, CPU, OS type and the number of histories per cycle. According to Table 1 and 2, it is inferred that the calculating condition cannot be ignored. It is the best to make the condition for the converged value like the case 11, but it takes tremendous time to execute. The execution circumstance was preferred to be Intel CPU and Win XP OS type for accessibility, lower histories per cycle and active cycle for minimizing execution time. In spite of some error, the result of the case 5 seems reasonable and this condition will be used for the future work. In addition, it is concluded that any MCNP modeling in future should consider and indicate the calculating condition.

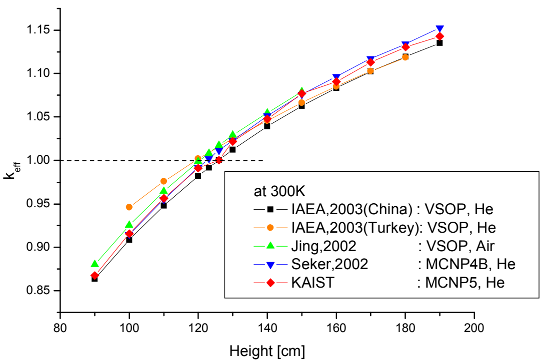

Figure 2. Variation of k_{eff} with core loading [1, 3]

4. Conclusion

The previous work for analyzing HTR-10 core has used the BCC lattice for modeling the core. To match the actual fuel to moderator ratio, the radius of moderator sphere had to be smaller. This was simple to use, but the accurate and sophisticated method were developed and employed in this study. Its basic unit for the core lattice was constructed in hexagonal prism. By comparing the result by using each simple BCC and accurate HEX method, it was figured out that HEX lattice provides more accurate result.

In addition, it was found that the outputs generated from the identical MCNP input were varied with computer conditions. Any MCNP modeling in future should pay attention to this impact.

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Table 1. Comparison of critical height [1]

Institution	Method/Code	Height[cm]
INET	Experimental	**123.06**
INET	Diffusion&Transport/VSOP94	125.80
HU	Diffusion&Transport/VSOP94	119.27
NRG	Diffusion&Transport/PANTHER	122.1
FZJ	Monte Carlo/TRIPOLI4	117.37
MIT	Monte Carlo/MCNP4B	127.5
KAIST	Monte Carlo/MCNP(HEX)	**122.65**
	Monte Carlo/MCNP(BCC)	**120.15**

Table 2. Difference of k_{eff} with various executing condition

At the calculated full loading height, 180.114 cm						
Case	MCNP ver.	CPU/ OS	No. histories	Total cycles	k_{eff}	△k_eff
1	5	Intel/ WinXP	2000	40	1.13198	0.00153
2	5	Intel/ Linux	2000	40	1.13048	0.00003
3	4C	Intel/ WinXP	2000	40	1.13242	0.00197
4	4C	AMD/ WinXP	2000	40	1.13546	0.00501
5	5	Intel/ WinXP	5000	60	**1.13140**	**0.00095**
6	5	Intel/ Linux	5000	60	1.13089	0.00044
7	4C	Intel/ WinXP	5000	60	1.13443	0.00398
8	4C	AMD/ WinXP	5000	60	1.13799	0.00754
9	5	Intel/ WinXP	10000	60	1.13004	-0.00041
10	4	Intel/ WinXP	10000	60	1.13596	0.00551
11	5	Intel/ WinXP	10000	210	**1.13045**	**Ref.**
12	5	Intel/ Linux	5000	210	1.13084	0.00039
13	4C	Intel/ WinXP	5000	210	1.13547	0.00502
14	4C	AMD/ WinXP	5000	210	1.13794	0.00749

REFERENCES

[1] IAEA-TECDOC-1382, Evaluation of high temperature gas cooled reactor performance: Benchmark analysis related to initial testing of the HTTR and HTR-10, IAEA, 2003.

[2] J. F. Briesmeister, Ed., MCNP-A General Monte Carlo N-Particle Transport Code, Version 4C, LA-13709-M, April 2000.

[3] Volkan Seker et al., HTR-10 full core first criticality analysis with MCNP, Nuclear Engineering and Design, Vol.222 2003.