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Neutronic Analysis of HTTR Core Using DeCART Code

Chang Joon Jeong*, Hyun Chul Lee, and Jae Man Noh

Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: cjjeong@kaeri.re.kr*

1. Introduction

The neutronic analysis for the High Temperature Engineering Test Reactor (HTTR) has been performed. The HTTR is a graphite-moderated and helium gas cooled reactor with an outlet temperature of 950℃ and thermal output of 30 MW [1]. It has been studied as one of the Generation-IV (Gen-IV) reactor.

In this study, the DECART code [2] is used with a 190-group KARMA library. The calculation results are compared with those of the McCARD [3] with ENDF-B/VII.0 library.

2. HTTR Core Model

Fig.1 shows the radial core arrangement, and the HTTR core specifications are represented in Table I. The HTTR core is a form of the annular type. The reactor core component is arranged in the reactor pressure vessel which has 13.2 m height and 5.5 m diameter. The core is consists of 30 fuel columns and 7 control rod guide columns with active core height of 290 cm and 230 cm effective diameter. An additional 9 control rod columns are located in the outer reflector region. The replaceable reflector region adjacent to the active core consists of 9 control rod columns, 12 replaceable reflector columns, and 3 irradiation columns. There are 2 top reflector blocks, 5 fuel blocks, and 2 bottom reflector blocks in each fuel column.

3. Results and Discussion

In this study, analysis has been carried out for center layer of the core, in which 4.3, 5.2, 5.9 and 6.3 wt% U-235 enrichment fuels are loaded. The single cell and block calculations have been performed for 5.2 wt% U-235 fuel.

Fig.2 shows the single cell and block model. Table II shows the temperature variation results for the HTTR single cell and block model. Here, T_m and T_f stand for the moderator temperature and fuel temperature, respectively. From the single cell results, the DeCART code generally underestimates the k_{inf} value. It can be seen that the errors of the DeCART code are quite small within -41.5 pcm.

For the single block temperature variation results, the DeCART underestimates the k_{inf} values at the entire temperature range, which is similar to that of the single cell model case. The maximum error of the k_{inf} value is ~80 pcm at a moderator temperature of 700K.

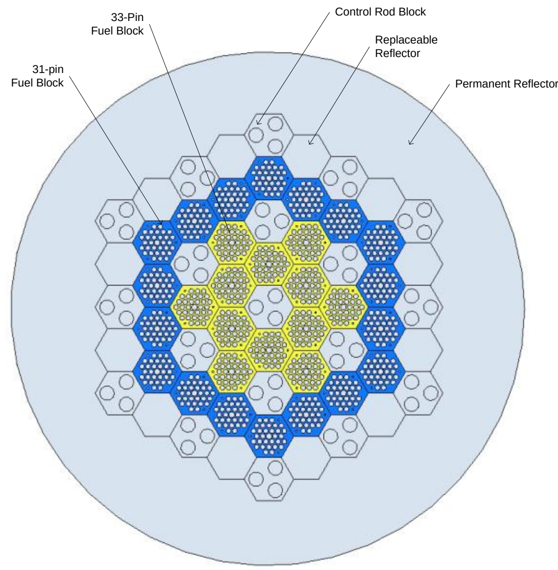

Fig.1 HTTR core model

Table I: Specification of the HTTR

Parameter	Value
Thermal power	30 MW
Outlet coolant temperature	950℃
Inlet coolant temperature	395℃
Equivalent core diameter	230 cm
Effective core height	290 cm
Uranium enrichment	3 to 10 wt%
Fuel type	Pin-in-block
Number of fuel blocks	150
Number of fuel columns	30
Number of control rod block	
In core	7
In reflector	9

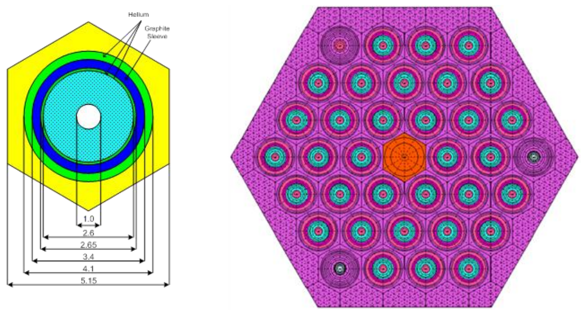

Fig.2 Single cell and block model

Table II: Temperature variation results for single cell and block model

T_m [K]	T_f [K]	$\Delta\rho$ [pcm]	
		Single Cell	*Single Block*
700	700	11.5	-42.5
700	800	-20.3	-69.8
700	900	-9.4	-77.8
800	800	22.9	-41.9
800	900	6.9	-50.4
800	1000	3.2	-51.7
1000	1000	-16.6	-57.9
1000	1100	-41.5	-63.1
1000	1200	-77.6	-57.4
1200	1200	10.6	-10.3
1200	1300	-13.4	-24.6
1200	1400	-24.4	-35.2
1200	1500	-30.8	-30.7

Fig.3 shows a DeCART 1/6 model of a 2-D core HTTR. Table III shows the temperature variation results for the HTTR 2-D core model with different reflector temperature Tr. A relatively large k_{inf} error was observed at a high moderator temperature. In addition, the reflector temperature effect was not much in total reactivity variation.

From the temperature coefficient analysis results, it is known that the moderator temperature coefficient (MTC) and fuel temperature coefficient (FTC). DeCART overestimates the MTC, while slightly underestimating the FTC when compared to those of the McCARD. For both the MTC and FTC, DeCART shows a very small error.

The depletion results gives maximum reactivity error in the case with BP is about 740 pcm during the depletion calculation. However, the trend between McCARD and DeCART is very similar each other.

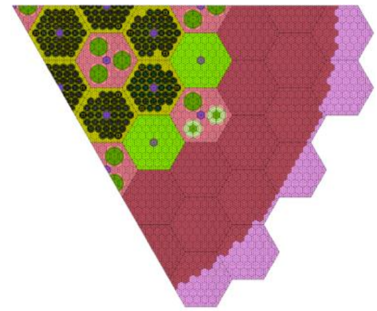

Fig.3 DeCART 2-D model for HTTR

Table III: Temperature variation results for 2-D core

T_m [K]	T_f [K]	$\Delta\rho$ [pcm]	
		Tr=700K	Tr=1000K
700	700	458.8	-
700	900	454.7	-
800	900	495.9	-
1000	1000	522.1	508.0
1000	1200	522.6	491.1
1200	1200	563.3	550.9
1200	1300	550.3	538.8
1200	1500	550.1	523.4

4. Summary

From the analysis results, it is known that the DeCART code generally underestimates the k_{inf} with moderator temperature variation. Also, it can be seen that the DeCART code predicts less negative MTC than the McCARD code does. However, the DeCART code gives a slightly more negative FTC value. From the depletion results, the error of the DeCART increases along the burnup, but the trend is very similar between two codes.

REFERENCES

[1] Japan Atomic Energy Research Institute, “Present Status of HTGR Research and Development,” JAERI, Oarai, Japan, 1996.
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