Simulation on the HTTR Control Rod Withdrawal Test

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1. Introduction

This paper describes the GAMMA+ code [1] simulation of HTTR control rod withdrawal test. The simulation is done to examine the effect of GAMMA+ code's single-zone and multi-zone point kinetics models on the prediction of the reactor power response during HTTR control rod withdrawal test. In addition, it has an objective to examine how the reactor power response is affected by the application of the fuel temperature coefficients on TRISO kernel or compact rod.

The calculation results of reactivity response and reactor power response are compared with the test results which were obtained at the initial power of 15.2 MW with the amount of reactivity insertion by control rod withdrawal to 3.4e-04 (dk/k) in 6.59 seconds.

2. Calculation Conditions of Control Rod Withdrawal Test

As a V&V calculation, the GAMMA+ code simulation is performed for the HTTR control rod withdrawal test [2]. In detail, this paper intends to examine the effect of GAMMA+ code's single-zone and multi-zone point kinetics models on the prediction of the reactor power response during HTTR control rod withdrawal test. In addition, it has an objective to examine how the reactor power response is affected by the application of the fuel temperature coefficients on TRISO kernel or compact rod.

KAERI has performed the V&V calculations of GAMMA+ code using HTTR LOFC Run-1 test [3]. During the simulation of HTTR LOFC Run-1 test, the point kinetics parameters for the reactivity change due to Xe-I concentration and the temperature coefficients of the reactivity of HTTR fuel block were provided by JAEA. The temperature coefficients parameters JAEA provided for the Run-1 simulation were based on the multi-zone model of the fuel block which is composed of 5 axial blocks and 4 radial regions in the core as shown in Fig. 1.

On the other hand, during the simulation of HTTR control rod withdrawal, JAEA used the point kinetics parameters of the single-zone model test as shown in Table 1 [2]. The parameters for the reactivity change due to Xe-I concentration and the axial power distribution of each fuel block zone in the LOFC Run-1 simulation [3] are applied for both the multi-zone model and the single-zone model for the simulation of HTTR control rod withdrawal. At the initial power of 15.2 MW, the amount of reactivity insertion by control rod withdrawal reached to 3.4e-04 (dk/k) in 6.59 seconds. The reactor outlet coolant pressure is 3.16 MPa, the inlet coolant temperature is 241.4 ^{o}C and the helium coolant flow rate in the reactor core is 12.4 kg/s.

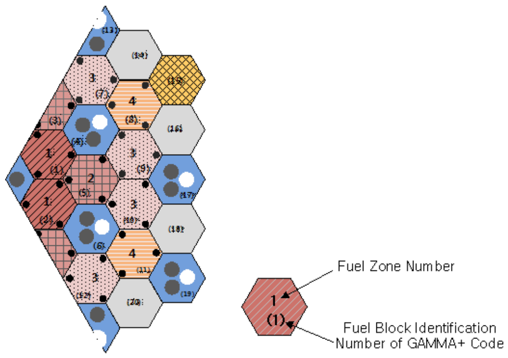

Fig. 1 Fuel Block Zone of HTTR Core

Table 1. Point Kinetics Parameters of Single-Zone Model

Parameters	Values
Initial reactor power (MW)	15.2
Withdrawal time (sec)	6.59
Increased reactivity by control rod (%dk/k)	0.034
Fuel temperature coefficient (dk/k/C)	-4.5e-5
Moderator temperature coefficient (dk/k/C)	-3.1e-5
Prompt neutron life time (sec)	9.4e-4

3. Results of No TRISO Kernel Model

Fig. 2 shows the GAMMA+ simulation results of the reactor power response during HTTR control rod withdrawal, in which the temperature coefficients were applied on the fuel compact rod instead of TRISO kernel particle (No TRISO Kernel Model). During the control rod withdrawal event which is a fast transient, the total reactivity is mainly affected by the inserted reactivity and the reactivity response due to the change of the fuel temperature and the graphite moderator temperature. Like the reactivity response, in the cases of the single-zone model and the multi-zone point kinetics model, the GAMMA+ simulation result of peak reactor power was a 3.5% and 3.0% higher with 4 seconds of time delay than the measured data.

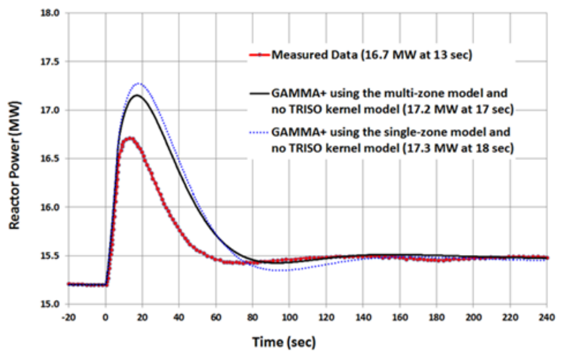

Fig. 2 Reactor Power Response (No TRISO Kernel Model)

4. Results of TRISO Kernel Model

In case of TRISO Kernel Model, it is shown that the GAMMA+ simulation results of the reactivity response were very close to the measured data for both cases of the single-zone model and the multi-zone point kinetics model. This result means that the better prediction could be obtained by the application of the temperature coefficients on TRISO kernel particle for the fast transient event of control rod withdrawal. Fig. 3 shows the GAMMA+ simulation results of the reactor power response during HTTR control rod withdrawal, using TRISO Kernel Model. In both cases of the single-zone model and the multi-zone point kinetics model, the GAMMA+ simulation result of peak reactor power was a 1.5% higher with 2 seconds of time delay than the measured data. That is, TRISO Kernel Model produces a better prediction as well as no difference between the single-zone model and the multi-zone point kinetics model. Fig. 4 shows the GAMMA+ simulation results of the fuel temperature response during HTTR control rod withdrawal, using TRISO Kernel Model. The peak temperatures of TRISO kernel and fuel compact are 1230 ^{o}C at 50 seconds and 1130 ^{o}C at 63 seconds during HTTR CRW Test, respectively. Due to the higher temperature gradient of TRISO kernel, the application of fuel temperature coefficient on TRISO kernel makes a faster power feedback than fuel compact model.

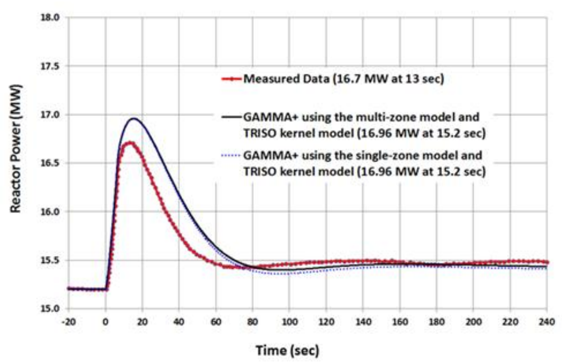

Fig. 3 Reactor Power Response (TRISO Kernel Model)

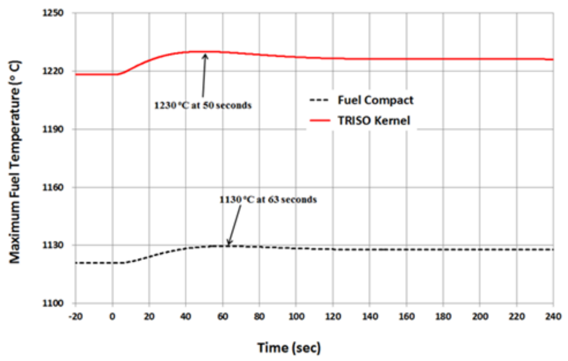

Fig. 4 Fuel Temperature Response (TRISO Kernel Model)

5. Conclusions

All GAMMA+ simulation results on a HTTR CRW test showed good predictions with the measured data. In particular, TRISO Kernel Model where the fuel temperature coefficients applied on the TRISO particle produced a better prediction within a 1.5% measured data and made no difference between the single-zone model and the multi-zone point kinetics model. During the control rod withdrawal event which is a fast transient, the total reactivity is mainly affected by the inserted reactivity and the reactivity response due to the change of the fuel temperature and the graphite moderator temperature. Unlike the slow transient of LOFC test, it is shown that the reactivity response due to the Xe-I concentration change is very small.

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