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Calculation of Fission Products Inventory for HTR-10

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1. Introduction

To analyze severe accidents in high temperature gas-cooled reactors (HTGR), the radioactivity in normal operation should be fundamentally provided first. The analysis of source term has not definitely performed for HTGR. Experimental measurement data and few simulation results by unpublished code packages were only available. However those data cannot be applicable to predict the general source term of HTGR, because the inventory of fission products depends on reactor and burn-up circumstance. The information of source term is fundamental and essential where the reactor safety assessment starts from. Nevertheless, this field has not been investigated much as its importance and the existing code such as ORIGEN has used. Especially, the general methodology of estimation on source term of HTGR is not provided yet, even though the HTGR comes into the spotlight as one of Gen4.

Therefore, in this study, the purpose is to calculate the source term inventory of core, especially HTR10, during the normal operation.

2. Method

The calculations for fission products estimation are usually performed within the context of the requirements of reactor physics studies such as in-core fuel management and fuel cycle analysis simulations. In addition, the codes are usually complex and require the use of multi-group neutron spectra and cross sections to estimate the composition of the nuclear fuel as a function of both space and time. The ORIGEN code offers the neutron cross sections only for basic reactors, except HTGR. The neutron cross section and flux should be generated and it can be achieved by the code combination of MCNP-ORIGEN-MONTEBURNS for depletion calculation, as shown in Figure 1. [1,2,3]

There are many HTGRs, however HTR-10 developed in China is selected as the reference reactor for estimating the source term. The reasons are: there is sufficient open information for HTR-10 and it has the small size core.

A double-heterogeneous MCNP spherical model was constructed to simulate the core. The first heterogeneity is in TRISO for fuel pebble, and the second heterogeneity is 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 lattice, and the basic unit of the core lattice is constructed in hexagonal prism in this study for satisfying the fuel-to moderator pebble ratio, 57:43 [4]. With design values by Terry [4], the core modeled by MCNP is depicted in Figure 2. The fuel management during operation up to 80GWD/MTU is described in Figure 3.

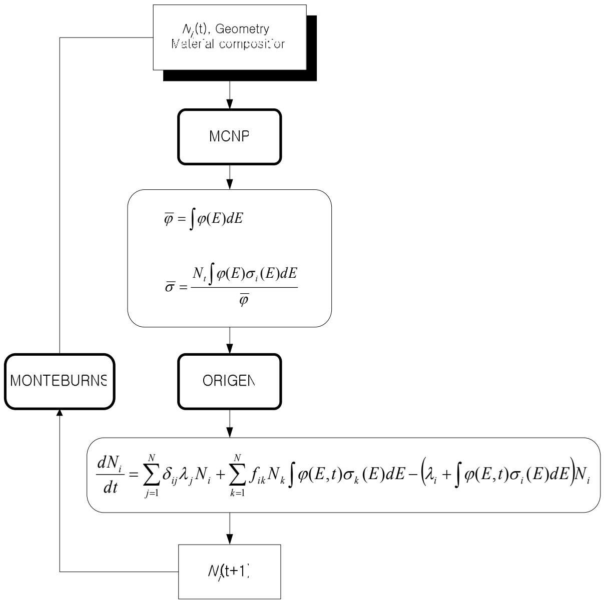

Figure 1. Burn-up calculation using MCNP-ORIGEN-MONTEBURNS

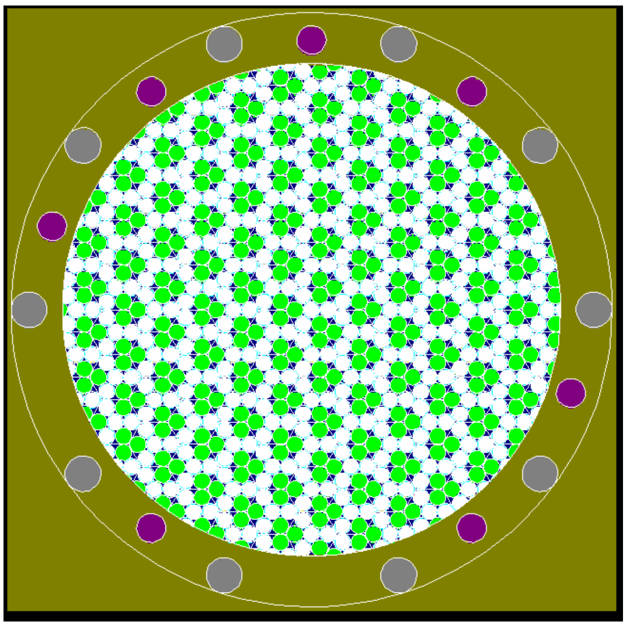

Figure 2. Spatiotemporal concentration distribution

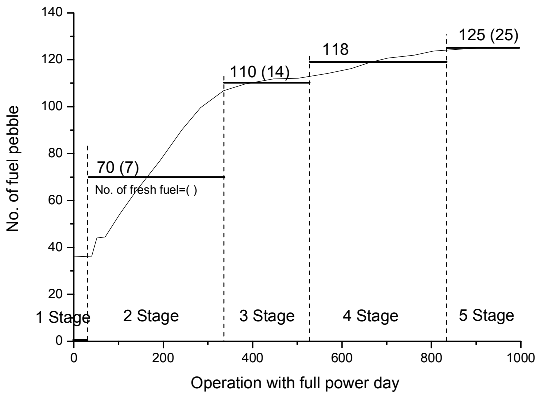

Figure 3. Fuel management for MONTEBURNS [5]

3. Results

The result of MCNP simulation was compared with the previous studies for the same conditions. It can be found that Monte Carlo calculations yield slightly higher k_{eff}, though the trend of curves is identical. In addition, it is shown in the Figure 4 that the reactor core maintains super-criticality and is operated with full power.

The published inventory data for HTR-10 was hard to be achieved. The reference inventory by Liu [6], as shown in Figure 5, is calculated using only ORIGEN2. Using single ORIGEN itself can give blunder results due to wrong neutron cross section and flux. The difference by Liu comes from the ignorance of the unique characteristics of core, though the trend of two curves is similar.

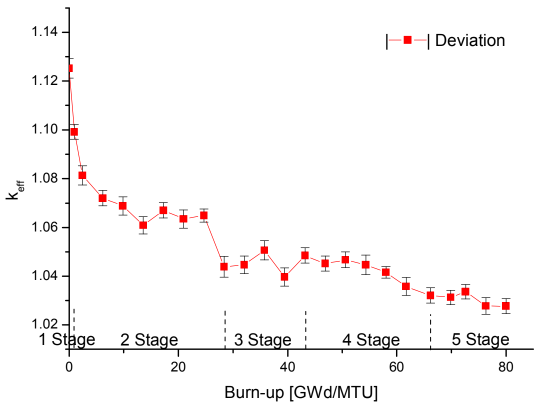

Figure 4. Reactivity variation with time

4. Discussion

There are some difficulties to predict the exact inventory. First, the reactivity could not be kept constantly. This may have a certain effect on the fission products generation. Second, the cross sections for real reactors need to be provided and they can be generated using NJOY code for the different temperatures circumstance with existing library, such as ENDF. However, this is not handled here, and cross sections used in this study were a default for the temperature, 300K. Third, the neutron streaming effect in coolant was ignored.

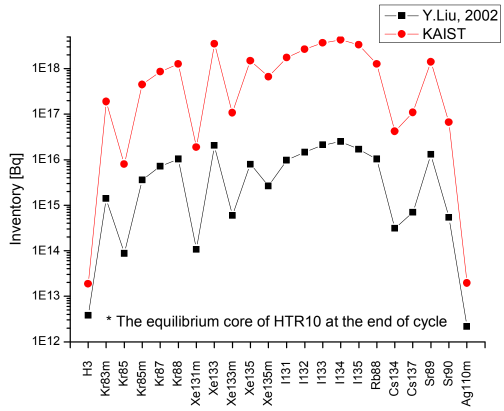

Figure5. Fission products inventory for HTR-10

5. Conclusion

The HTGR design for hydrogen in Korea has not yet been selected. This study can provide fundamental information where the safety assessment of the new HTGR design starts from. It should be stressed that the evaluation of the source term inventory is the first work to be done for nuclear safety and the general methodology of it has been developed in this study.

ACKNOWLEDGMENT

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