Preliminary Assessment of Double Heterogeneity Capability of SCALE system

GwanYoung Kim [a*] and Changwook Huh [a]
[a] *Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon, Republic of Korea*
[*] *Corresponding author:k722kgy@kins.re.kr*

1. Introduction

HTGR fuel is composed of a large number of tiny tri structural-isotropic (TRISO) fuel particles embedded in a graphite matrix and each fuel particle has a spherical fuel kernel that is covered by carbon-based layers. The use of TRISO fuel particle results in the inherent double heterogeneity (DH) which makes it more difficult to model and requires methods different from those used for a typical LWR fuel.

The SCALE (Standardized Computer Analysis for Licensing Evaluation) system [1,2] has introduced a capability to model doubly heterogeneous systems and the DH cross section processing treatment in SCALE has been validated over and over. Those most validations are limited to a comparison with the repeated and latticed fuel particles.

In this study, the fuel element with random-distributed fuel particles is modeled and analyzed in MCNP code [3]. The DH capability of SCALE system is assess by comparing the SCALE results with those MCNP results.

2. Methods and Results

2.1 Double Heterogeneity Treatment Process in SCALE system

SCALE system provides the capability for treating doubly heterogeneous system by using the point-wise (PW) flux disadvantage factors that are calculated with 1-D point-wise S_N code, CENTRM.

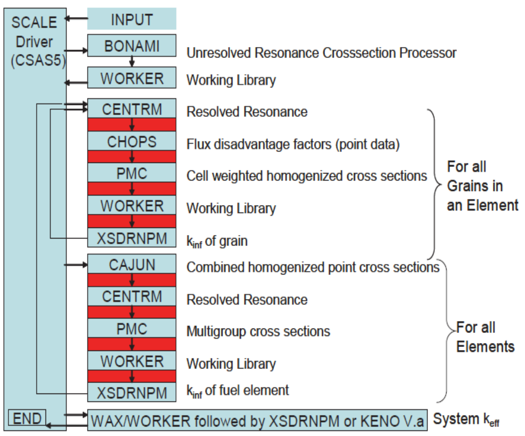

Fig. 1. DH treatment process in SCALE system

The DH treatment process in SCALE system is delineated in Fig. 1. First, the PW flux disadvantage factors in the fuel particles are calculated. Then, these PW flux disadvantage factors are used to generate the cell-weighted PW cross sections for the homogenized fuel region in the fuel elements. Finally, these spatially averaged PW cross sections are used to calculate the flux distribution in the fuel element, which is then used to generate the multi-group problem-dependent cross sections.

2.2 Fuel specification and Analysis

The VHTR demonstration plant, PMR200 which is based on the prismatic, graphite-moderated reactor design is developed at the KAERI. The fuel particle and the fuel element of the PMR200 core are shown in Fig. 2. The TRISO fuel particle is comprised of fuel kernel and 4 coating layers - Buffer, Inner PyC, SiC, Outer PyC. These TRISO fuel particles are randomly distributed in the fuel compact region of fuel element. The enrichment is approximately 14 wt% U-235 with a packing fraction of 0.235.

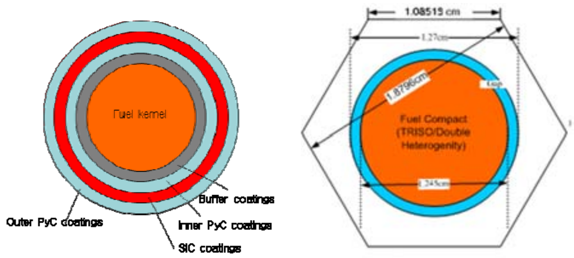

Fig. 2. Fuel element and fuel particle

To assess the DH capability of SCALE system, a comparison of the results from SCALE and MCNP5 code is performed for two cases, a DH case and a homogeneous case. A homogeneous case is made by homogenizing the isotopes in fuel compact region of DH case with keeping the number density of isotopes.

For simulating the DH in MCNP5, all of random-distributed fuel particles are modeled via the script-code which does randomly generate the location of a particle after checking out whether the particle overlaps other particles. This job repeats as many as the number of fuel particles corresponding to the packing fraction. Finally, the location information of all particles which are randomly distributed without any overlapped with each other, is entering into a MCNP5 input file. Fig. 3

shows the horizontal section of MCNP5 modeling by using the script-code.

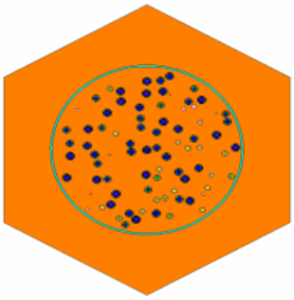

Fig. 3. Horizontal section of MCNP model

The MCNP5 uses continuous energy cross sections and SCALE system uses 238-group cross section libraries because SCALE system cannot use the continuous energy group library when DH treatment process is applied. In both cases, the nuclear data libraries were based on ENDF/B-VII.0.

2.3 Results

In order to evaluate the DH capability of SCALE system, the infinite multiplication factor (k-inf) and the flux of SCALE system simulation are compared with those of MCNP code simulation for a DH case and a Homogeneous case.

The k-inf calculated from two codes list in Table I. The k-inf from SCALE system is lower than that from MCNP code by about 791 pcm in a DH case. The difference is also existed as much as 450 pcm in a homogeneous case which has no relation to a DH. That is to say, a difference between two codes already exists due to the nuclear data library as distinct from the DH capability of SCALE system. Thus, a difference resulting only from the DH capability of SCALE system can be assessed by a factor of a DH effect, which is calculated from results of a DH case and a homogeneous case. A DH effect from SCALE system is lower than that from MCNP code by about 341 pcm, which is about 9 % of a DH effect from SCALE system.

Table I: Comparison of k-inf

Code / case	SCALE	MCNP5	Δ ρ (pcm)
DH case	1.39494 ± 0.00014	1.41050 ± 0.00119	790.8
Homogeneous case	1.32594 ± 0.00016	1.33390 ± 0.00123	450.0
DH effect (pcm)	3730.5	4071.3	340.8

The spectrums of SCALE result and MCNP result in a DH case are compared shown in fig. 4. These spectrums are extracted from the fuel element region. The relative error is less than 3 % except 2 ~ 4 eV region where the maximum error is almost 15 %. However, that aspect is also appeared in a homogeneous case.

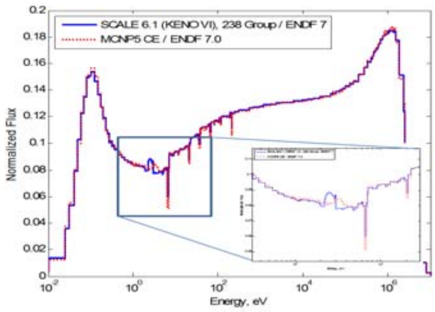

Fig. 4. Comparison of spectrums in DH cases

3. Conclusions

The SCALE system is investigated to utilize this code as VHTR analysis code. In this study, the DH capability of SCALE system is assessed by comparing the MCNP code with random-distributed model. As a result, a DH effect from SCALE system show a not a small difference with MCNP reference result.

This study is insufficient to fully assess the DH capability of the SCALE system. More thorough assessments should be done utilize the SCALE code as VHTR analysis code and is in plan as a future study.

REFERENCES

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