Preliminary Analysis for the Irradiation of a TRISO particle in HANARO

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1. Introduction

An irradiation test of a TRISO particle is planned at the irradiation hole in HANARO. The fuel kernel of TRISO is 12w/o UO_2. A target power is being considered as 200~300mW/particle of TRISO[1]. Prior analyses showed that the power of 12w/o TRISO would be much higher than the target power[2]. Thus, a preliminary study on the determination of the enrichment of a TRISO particle is performed and its result is presented in this paper.

2. Calculation and Result

In this section a calculation model to simulate the irradiation condition of TRISO particle and the results are described.

2.1 Calculation Condition

The TRISO particle will be irradiated at one of four outer core irradiation holes, OR5, at HANARO in which most of the irradiation tests for fissile materials using an irradiation rig have been conducted. For the MCNP simulation, a simple core of fresh clean condition has been utilized for the preliminary analysis because it is impossible to anticipate an actual core condition at this time due to many different irradiation activities. The four CARs are assumed to be inserted by 5/14 considering its moving range during normal operation. Al dummy assemblies are loaded in three in-core irradiation sites, CR, IR1 and IR2. The TRISO particles are placed at an axial center for an active fuel height of 700mm.

Three test rod types are being taken into consideration. Rod 1 has 9 holes of 0.46mm in radius and 46mm in height and each has 50 TRISO particles. In rod2, TRISO particles are dispersed in graphite matrix. Rod 3 has disks of clad materials such as SiC, carbon. They are arranged in a triangular shape in an irradiation rig. The TRISO particles are not modeled separately but homogenized in this preliminary calculation. The calculation is done in a KCODE mode with 70,000 particles per cycle and 500 cycles to obtain a reasonable result within an acceptable computing time. Fig. 1 shows the cross-sectional view of the rig and its MCNP model.

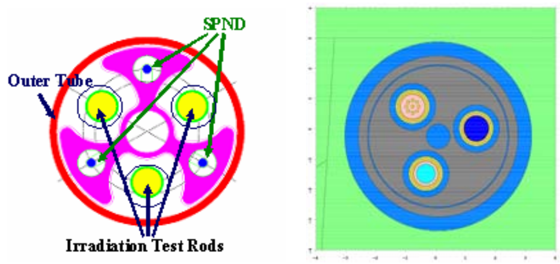

Fig. 1. Irradiation rig concept of TRISO particle and its MCNP model at OR5 hole in HANARO

2.2 Proper Enrichment for TRISO irradiation

From the previous study for the 12w/o UO_2, a proper enrichment to satisfy the power requirement of an average 250mW is calculated to be ~4w/o[3]. The power at a TRISO particle is calculated by changing the enrichment from 4 to 6. It is assumed that only the amounts of U^{235} and U^{238} are varied according to the enrichment change but the others of O, Si and C are constant in the homogenized composition because the power is dependent on only fissile materials. Table I shows the weight fraction of each nuclide according to the enrichment for the homogenized rod 1.

Table I: Weight Fraction of Each Nuclide for Homogenized Rod 1 in MCNP Calculation

Nuclide	Weight fraction for different enrichment (%)				
	4%	4.5%	5%	5.5%	6%
U^{235}	1.823	2.051	2.278	2.506	2.734
U^{238}	43.743	43.515	43.287	43.060	42.832
O	6.127				
Si	12.013				
C	36.295				
Density	2.1738				

2.3 Power at TRISO Particle

Total number of 2.2642E+18 neutrons/sec is used as a normalization factor in the calculation by assuming 29.3MW_{th}, 196.75MeV/fission and a 2.436 fission neutron release from a fission. Since the calculation is performed for a fresh clean core, the calculated results are manipulated by dividing them by a multiplication factor and including a core burnup effect of 20%.

The average power at a TRISO particle in rod 1 is estimated to 217~322mW. The fractional standard deviations for the calculated powers range from 5% to 7%. Fig. 2 shows the average power per one TRISO particle according to the enrichment of UO_2.

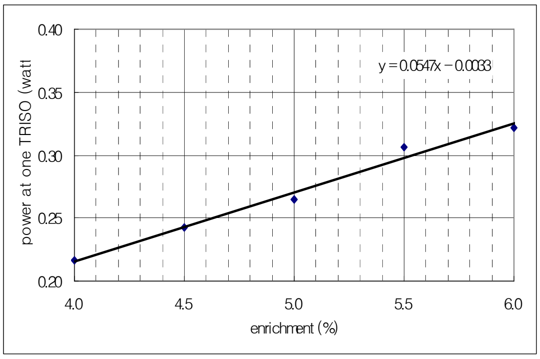

Fig. 2. Average power at a TRISO particle when it is irradiated at OR5 in HANARO

Thus the required UO_2 enrichment is about 4.6~4.7w/o from the above figure.

2.4 Heat Generation Rate

Each rod in the irradiation rig has inner and outer tubes. The heat generation rate due to mainly a gamma at these two tubes is evaluated together with that at the clad materials in rod 3.

The irradiation position OR5 is located near the CAR of Hf. The ENDF/B-VI data for Hf in the MCNP cross section library does not have gamma production data whereas ENDL92 has. To include the gamma produced at Hf, ENDL92 data for Hf is chosen. In the MCNP calculation, the prompt fission gamma, capture gamma and inelastic neutron scattering gamma are counted but the delayed gamma from the fission product decay is not included. The amount of heat due to a delayed gamma is inferred as less than one half of that due to the other gammas from previous experiences. Thus the total gamma heat generation rate is estimated by adding 50% to the MCNP calculated gamma heat as an effect from a delayed gamma.

The variation of the heat generation rates according to the enrichment change is negligible to be within the standard deviation. The heat rates at inner tubes in 3 rods are 2.1~2.61 watt/gm. Those at outer tubes in 3 rods are 2.22~2.72 watt/gm. And those at clad materials in rod 3 range from 1.33 to 1.78 watt/gm.

3. Conclusions

An enrichment of a UO_2 TRISO particle satisfying an average power of 250mW per particle is searched when the TRISO is irradiated at OR5 in HANARO. The required enrichment is estimated to be about 4.6~4.7w/o. In addition, heat generation rates at the inner and outer tubes and clad materials are calculated. Their change for an enrichment variation is negligible.

This analysis has been performed for specific core conditions with fresh fuels, typical CAR position, etc. A detail analysis should be conducted with an actual core condition in order to confirm the available target power. Factors that can influence the power at TRISO are the target irradiation position, CAR location, calculation uncertainty, etc. It is recommended to first decide on the enrichment with some margin and next decide on the irradiation position through a detail analysis.

Acknowledgement

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REFERENCES

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