The Effect of Target Material and the Neutron Spectrum on Nuclear Transmutation of ^{99}Tc and ^{129}I in Nuclear Reactors

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1. Introduction

Of the long-lived fission products in spent nuclear fuel, ^{99}Tc and ^{129}I are highly mobile in underground environment during disposal at a deep geological disposal repository. And they cause the exposure doses to the ecosystem mainly due to the release of beta rays of several hundred keV [1]. Therefore, if the two nuclides are separated from spent nuclear fuel and converted into short-lived nuclides or stable nuclides through nuclear transmutation in nuclear reactors, it can have a positive effect on safety for disposal. For this purpose, it is necessary to investigate the efficiency of transmutation of these two nuclides in the reactor. In this study, for variable nuclear reactor, the depletion calculation was performed using McCARD code [2], a neutronics analysis code of the nuclear reactor and fuel systems, and the results were compared and discussed in terms of nuclear transformations of ^{99}Tc and ^{129}I.

2. Target Material

Because ^{99}Tc has a high melting point and metal density, it is assumed to be a technetium metal target material for nuclear transmutation. On the other hand, due to be converted to gaseous xenon through beta decay, ^{129}I has a physical problem. The problem is that the melting point and boiling point of ^{129}I are lower than the core temperature and pressure. To solve this problem, CuI, CaI_2 and MgI_2 were assumed to be the chemical forms of the target material in consideration of the thermal and chemical properties of iodide [3].

In this study, the target materials were simulated using technetium metal, CuI, CaI_2 and MgI_2. Additionally, the isotope ratios of technetium and iodine were obtained from a typical PWR 16x16 nuclear fuel assembly burned up to the average discharge burnup (55000 MWD / MTU) [4].

3. Model

To simplify the calculation, only fuel assemblies and fuel bundle with the target material rod were modeled and calculated in 2 dimensions. PWR and CANDU are typically pressurized light water reactor type and heavy water reactor type. And PGSFR and MET-1000 are sodium cooled fast reactors. The difference between the two reactors is that PGSFR uses highly enriched uranium fuel and MET-1000 uses TRU as fuel [4~9]. In case of CANDU, PGSFR and MET-1000, the center rod of each assembly and bundle is replaced with the target material rod. Otherwise, the target material rod is loaded in the instrumentation tube in case of PWR.

After calculating the burnup to the average discharge burnup of each reactor [4~9], ^{99}Tc and ^{129}I of the target material rod in each case were examined.

4. Comparison of simulation results

4.1 Comparison of ^{129}I nuclear transmutation ratio by target materials

Fig. 1 shows the nuclear transmutation ratio of ^{129}I when the iodide target materials are loaded in each reactor and that the results of each target material are similar.

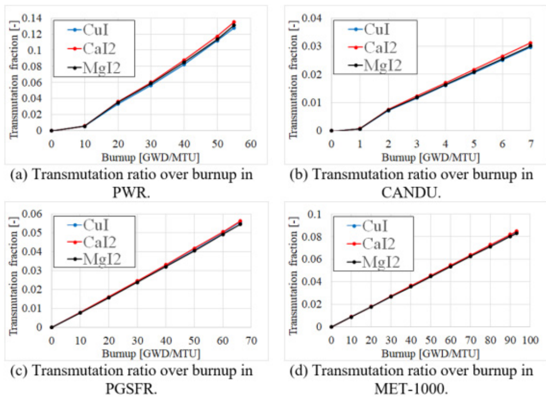

Fig. 1. Transmutation ratio over burnup in each reactor.

On the other hand, as shown in Fig. 2, the transmutation amount of ^{129}I of MgI_2 is higher than the others considering the densities of iodine.

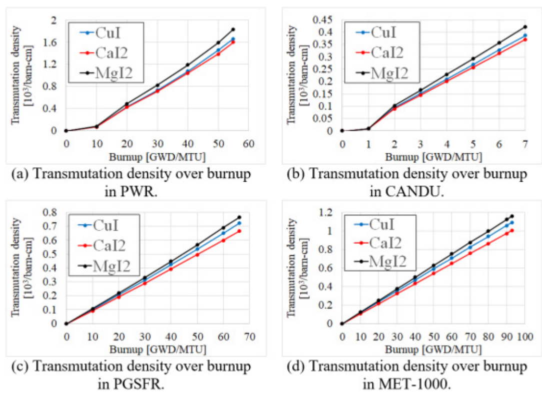

Fig. 2. Transmutation density over burnup in each reactor.

4.2 Comparison of nuclear transmutation ratio by each reactor

As shown in Fig. 3, total transmutation ratios of ^{99}Tc and ^{129}I in case of PWR are more than in the other cases due to relatively larger the transmutation rate and the average discharge burnup. On the other hand, in case of CANDU, transmutation rate is larger than the others, but due to the shortest average discharge burnup, total transmutation ratio is the shortest.

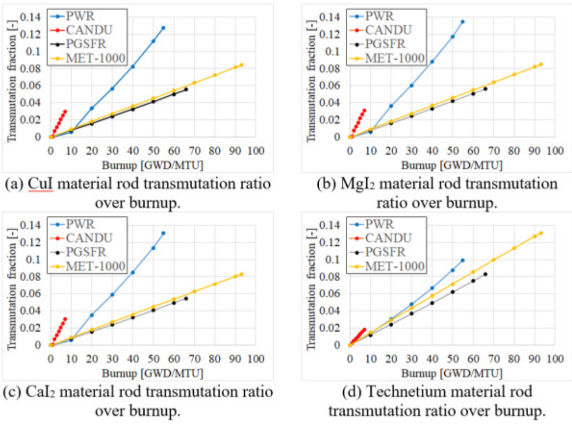

Fig. 3. Transmutation rate of each target material over burnup.

5. Conclusion

The fuel assemblies of PWR, PGSFR and MET-1000 and the fuel bundle of CANDU are modeled with target materials and performed depletion calculation using the McCARD code.

As a result of transmutation ratio comparison, the nuclear transmutation ratios of the three target materials (CuI, CaI_2 and MgI_2) are almost the same, but MgI_2 is the most amount of transmutation during the same burnup.

CANDU has the most transmutation rate, but has the shortest transmutation ratio due to the shortest average discharge burnup. On the other hand, PWR has less transmutation rate than CANDU, but has the most transmutation ratio consideration in the average discharge burnup and transmutation rate.

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