Analysis of Americium Migration in the Metal Fuel for SFR

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1. Introduction

A metallic fuel is being developed for SFR (sodium-cooled fast reactor) in Korea. The fuel slug is basically U-TRU-Zr of which composition depends on a pyroprocessing. A radial fuel constituent migration is a general phenomenon in the metallic fuel. The migration of Am (Americium) as well as other fuel constituents such as U and Zr affects the in-reactor performance of metallic fuel rods. Since the migration of Am might be related to that of Zr according to the X501 experiment, it is possible to develop the Am migration model based on the U-Pu-Zr migration model.

In this paper, the Am migration behavior was investigated. A subroutine program has been made and installed into the MACSIS code to simulate the Am migration. The radial profile of the Am migration was calculated for the U-TRU-Zr metallic fuel.

2. Methods and Results

In this section, the Am migration model and the calculations of the Am migration are described.

2.1 Am migration model

The radial fuel constituents migration related to the formation of three distinct phasal zones is a general phenomenon in irradiated U-Pu-Zr and U-Zr alloys [1]. This phenomenon affects the in-reactor performance of metallic fuel rods, such as the melting temperature, the thermal conductivity, the power generation rate, and FCCI (Fuel-Cladding Chemical Interaction). Thus, the migration model is essential to develop a metallic fuel performance code.

One of the factors that may limit burnup in metallic fuel is cladding wastage due to reaction of fuel constituents and fission products with the cladding. The inclusion of MA (Minor Actinide) to U-Pu-Zr may also increase FCCI by the Am migration.

In order to evaluate the constituent migration for the Am bearing fuel, the results of the X501 minor actinide burning experiment [2] were investigated. The X501 experiment is one of the few MA-bearing fuel irradiation tests.

Figure 1 shows the WDS line scans showing distribution of Actinide and Zr.

The outer zone and the central zone are enriched in zirconium. However, the intermediate zone is zirconium depleted.

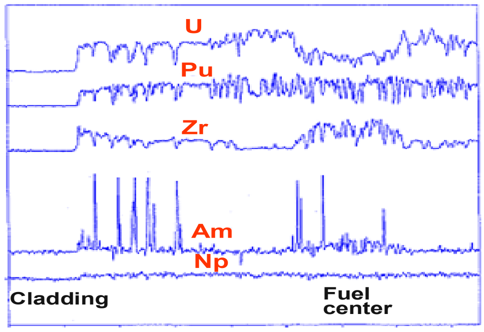

Fig.1 Radial distribution profile of X501 tests

Am was observed at the fuel outer regions and the Am precipitates were also found at the hottest fuel center region. This result indicated that the migration of Am was related to that of Zr, because Am was only present in the Zr enriched zones. So it is assumed that the migration behavior of Am is similar to that of Zr.

The Am migration model for U-TRU-Zr was developed by using the U-Pu-Zr migration model [3] which was developed based on the Ishida's model [4] and Hofman's theory [5].

The subprogram for analyzing the Am migration was inserted into the MACSIS code. The subprogram includes the quasi-binary U-Zr phase diagram which was reconstructed by Ishida's concept. The diffusion equations for the constituent migration at single, multi and boundary phases are also included in this subprogram.

2.2 Calculation of the Am migration

The Am migration was calculated by using the X501 data and the MACSIS code.

The key parameters for the Am migration analysis are shown in Table 1 [6].

Table 1. Key parameter

Composition of fuel slug [wt%]	U-20.2Pu-10Zr-1.2Am-1.3Np
Outer diameter of cladding [mm]	5.84
Thickness of cladding wall [mm]	0.457
Outer diameter of fuel slug [mm]	4.27
Smeared density [%]	75
Linear heat generation rate[kW/m]	45
Cladding material	HT9

Figure 2 shows the calculated and measured radial distribution profile of Zr. The dashed line means the initial Zr concentration. The rectangular points mean the experimental data. The main reason for the migration is the radial solubility change of Zr. The heat of transport also playes an important role in the migration.

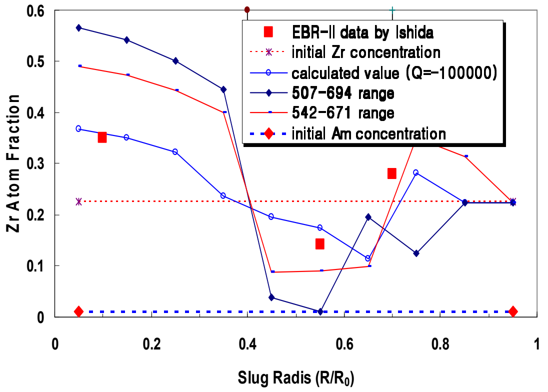

Fig. 2 Radial distribution profile of Zr

It was calculated that the depletion of Zr in the middle zone was simulated well, in this case the value of the heat of transport was more than -100,000kJ/mole.

The migration behavior of Am is similar to that of Zr, so -100,000kJ/mole of the heat of transport was also used to calculate the Am migration behavior.

Figure 3 shows the simulated Am migration for the X501 fuel.

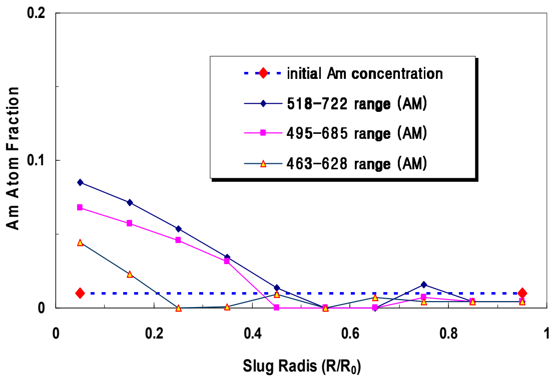

Fig. 3 Radial distribution profile of Am

This calculation showed that the Am migration along with the migration of Zr was simulated well by the Am migration model.

At around 700℃ of the fuel centerline temperature, the model predicts the Am fraction in the fuel center reaches its peak of 0.08. There were be no centerline Am depletions expected in all range of temperature.

Even though the local radial migration of Am to the cladding inner wall did not occur at the X501 experiment; however these results do not rule out the possibility of the Am condensation at the cladding inner wall in any in-reactor conditions.

The model predicts that the Am enrichment occurs at the fuel surface when the fuel surface temperature approaches the ($\zeta+\gamma$) phase boundary. This phenomenon has not been confirmed yet experimentally, but the fuel designers should consider on this effect for analyzing the performance or setting up their operating temperature limit.

3. Conclusions

The migrations of the fuel constituents such as MA, U, and Zr affect the performance of the metallic fuels. The Am migration behavior in the X501 experiment was investigated to develop the Am migration analysis model. The results of the X501 experiment showed that the migration behavior of Am is similar to that of Zr. The Am migration model based on the U-Pu-Zr migration model was developed.

The Am migration was calculated by the MACSIS code including the Am migration model. It was found that the Am migration was simulated well by the model.

Acknowledgements

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