Re-fabrication of U-Zr Alloy System Fuel Slugs Recycling Fuel Scraps

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1. Introduction

Sodium cooled fast reactors (SFRs) are considered Gen-IV reactors. The spent fuel generated in nuclear power plants is converted into uranium and TRU, a raw material for SFRs [1]. The U-TRU-Zr-RE metal fuel slug has been developed as a candidate fuel slugs for SFR. It has many advantages such as simple fabrication procedures, good neutron economy, high thermal conductivity, excellent compatibility with a Na coolant, and inherent passive safety [2-3]. It is fabricated using an injection casting method. The efficient fabrication process of U-TRU-Zr-RE metal fuel slug is largely based on an injection casting method. Nevertheless, reducing radioactive waste has been an important challenge worldwide and thus recycling of the slug should be considered. A considerable amount of fuel scraps upto 50% of charge amount for injection casting has been made consisting of the heel of the melt residue and unsuitable fuel slugs.

In this study, to increase the yield rate of injection casting, metallic fuel slugs were re-fabricated using fuel scraps consisting heel residue and unsuitable fuel slugs. The metallic fuel scraps have been treated on the impurity layer of the surface using chemical and mechanical method. And then, metallic fuel slugs have been re-fabricated for the recycling of the fuel scraps. After the surface treatment, metallic fuel slugs were re-fabricated using a heel residue and fuel slug butts as the raw material through an injection casting apparatus to evaluate the feasibility of the recycling of the fuel slug scraps.

2. Methods and Results

2.1 Experimental Methods

The metallic fuel scraps such as heel residue and slug butts of U-10wt.%Zr and U-10wt.%Zr-RE(rare-earth elements) fuels after injection casting were used as raw materials for re-fabrication of fuel slugs. RE is a rare-earth alloy consisting of 53wt%Nd, 25wt%Ce, 16wt%Pr, and 6wt%La. The metallic fuel scraps have been treated on the impurity layer of the surface by either chemical or mechanical method. Casting variables, e.g., casting temperature and pressure, pressurizing rate, mold coating method were adjusted with graphite crucibles coated with ceramic plasma-spray coating and quartz molds coated with slurry-coating. At a predetermined superheat, the mold was lowered with pressurization of atmospheric gas, immersing the open tip into the metal melt. The metallic fuel slugs were fabricated using recycled metallic fuel scraps by injection casting method.

To examine the soundness of the metallic fuel slugs, the density of the metallic fuel slugs was measured using an Archimedean immersion method. The alloy compositions of the metallic fuel slugs were investigated using inductively coupled plasma atomic emission spectroscopy (ICP) and an elemental analysis (EA). The microstructure and the composition of the metallic fuel slugs were analyzed using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS).

2.2 Experimental Results

Metallic fuel slugs consisting of U-10wt%Zr and U-10wt%Zr-RE with a diameter of about 5.5 mm and a length of about 300 mm were fabricated per batch. They were generally sound without cracks or thin sections, as shown in Fig. 1. Average density of the U-10wt%Zr fuel slugs were measured as 15.7g/cm^3. Average density of the U-10wt%Zr-RE fuel slugs was measured as 14.9 g/cm^3. The density of the metallic fuel slugs slightly differed according to the composition of fuel alloys. The measured densities of the metallic fuel slugs were considerably similar to the theoretical density of metallic fuel slug.

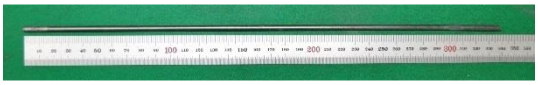

Fig. 1. Typical re-fabricated metallic fuel slug recycling fuel scraps.

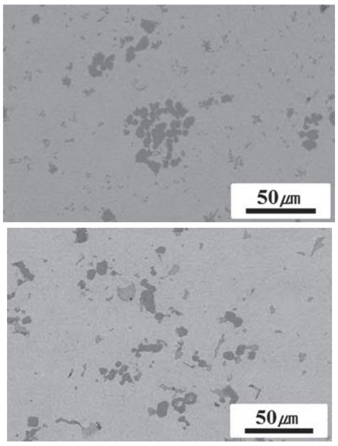

Fig. 2. Typical cross-section SEM images of re-fabricated metallic fuel slug; (a) U-10wt%Zr, (b) U-10wt%Zr-7wt.%RE.

Table 1. Chemical composition of recycled metallic fuel slugs

Alloy Composition	U-10wt.%Zr	U-10w.t%Zr-7wt.%RE
U (wt.%)	90.6	86.1
Zr (wt.%)	9.6	10.1
Nd (wt.%)	-	2.0
Ce (wt.%)	-	1.3
Pr (wt.%)	-	0.5
La (wt.%)	-	0.2
C (ppm)	87	237
N (ppm)	10	10
O (ppm)	653	430
Si (ppm)	239	379

Fig. 2 shows the microstructures of the respective metallic fuel slugs analyzed using SEM. All metallic fuel slugs were fabricated using heel scraps as the raw material. Metallic fuel slugs were fabricated using metallic fuel scraps added to a pure metal material. The precipitates were distributed uniformly at the top, middle, and bottom positions. A lot of Zr-rich precipitates or RE-rich inclusions were observed randomly in the metallic fuel slug. RE elements was separated as an inclusion with U-Zr alloy because of immiscibility. From the specifications of the fuel slugs, the total impurities of carbon, nitrogen, oxygen, and silicon must be less than 2,000 ppm. The chemical analyses of the fuel slugs showed that the total impurities were satisfied with the specification requirements, as shown in Table 1.

3. Conclusion

The recycling of metallic fuel scraps is necessary to maximize the utilization of the uranium resources. Metallic fuel slugs were re-fabricated using metallic fuel scraps including heel residue and unsuitable fuel slugs. The fuel slugs were generally sound and fabricated to the mold length of 300 mm. The total impurities of oxygen, carbon, nitrogen, and silicon were less than 2,000 ppm for the recycled metallic fuel slugs. The feasibility of the recycling of the fuel slug scraps has been demonstrated by the re-fabrication of the metallic fuel slugs. The recycling of the metallic fuel scraps would be able to contribute to the maximization of yield rate for the fabrication process of the fuel slugs.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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