

Fabrication of Metallic Fuel Slugs through Surface Treatment of Fuel Scraps

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1. Introduction

As a part of a Sodium-cooled Fast Reactor (SFR) fuel development, metallic fuel slugs have been developed as a nuclear fuel of Next Generation Nuclear Plant (NGNP). These metallic fuel slugs have been fabricated using an injection casting method. To develop metallic fuel slugs, a high yield rate is an important factor to decrease uranium scrap waste. After fabrication, a considerable amount of fuel scraps have been made consisting of the heel of the melt residue and unsuitable metallic fuel slugs. To increase the yield rate of metallic fuel slugs, metallic fuel slugs were refabricated using fuel scraps consisting of heel residue and unsuitable metallic fuel slugs. This re-fabrication process is described herein, and re-fabricated metallic fuel slugs were analyzed using density and SEM/EDX.

2. Methods and Results

The U-10wt%Zr-5wt%RE alloy was used as raw materials. To recycle the metallic fuel scrap but also suitable impurity content ($C + N + O + Si < 2,000$ ppm) must be required. The impurity content is most important in the specification requirements. The bulk of impurities exist at the surface of the metallic fuel scraps. After fabricating metallic fuel slugs, the coating layer and impurity layer reacted with a graphite crucible were produced at the surface of the heel residue, and the impurity layer reacted with quartz tube was partially formed at the surface of metallic fuel slug. To recycle the metallic fuel scraps, the surface treatment was physically carried to remove the impurities using a grinding and brushing method. After removing the surface impurity, heel residue and fuel slugs were suitably cut to insert into the graphite crucible. The metallic fuel scraps consisting of a heel residue and fuel slugs after surface treatment are shown in Fig. 1. Zirconium sponge, an RE ingot, fuel slugs, heel residue, and uranium metal were charged in the order named. The heel residue and fuel slugs were respectively charged at the 20 percent of the total charge amount. To prevent the graphite crucible from reacting with rare-earth elements, the graphite crucible was coated using a plasma-sprayed coating method. Plasma-sprayed coating can provide a crucible with a denser and more durable coating layer compared with the more friable coating layer formed through slurry-coating [5]. The

metallic fuel slugs were fabricated at 1450°C using an injection casting method.



(a)



(b)

Fig. 1. Metallic fuel scraps after surface treatment; (a) heel residue and (b) metallic fuel slugs



Fig. 2. Re-fabricated U-10wt%Zr-5wt%RE metallic fuel slugs

Fig. 2 shows re-fabricated U-10wt%Zr-5wt%RE metallic fuel slugs fabricated with an injection casting system. U-10wt%Zr-5wt%RE metallic fuel slugs were generally sound without cracks or thin sections. All fuel slugs with a diameter of about 5.5mm were fabricated per batch. A density measurement of the fabricated fuel slugs was performed to detect internal defects such as cracks and pores. Density provides an indirect indication of the internal defects and information concerning the melting or alloying conditions of the charged materials. When fuel slugs have defects or

pores, the density becomes lower than that of sound fuel slugs. Fig. 3 shows differences in density according to the position from top to bottom. The bottom region was the lowest position. However, it is almost uniform in density. In addition, the density value of a U-10wt%Zr-5RE metallic fuel slug has a higher value in comparison with the theoretical value of a U-10wt%Zr-5wt%RE metallic fuel slug.

Fig. 4 shows the SEM cross-section of U-10wt%Zr-5wt%RE. A lot of inclusions were observed randomly in the U-10wt%Zr-5wt%RE metallic fuel slug. Table I shows the results of an EDX analysis of the RE phase. The RE elements were separated as an inclusion with U-Zr alloy because of immiscibility.

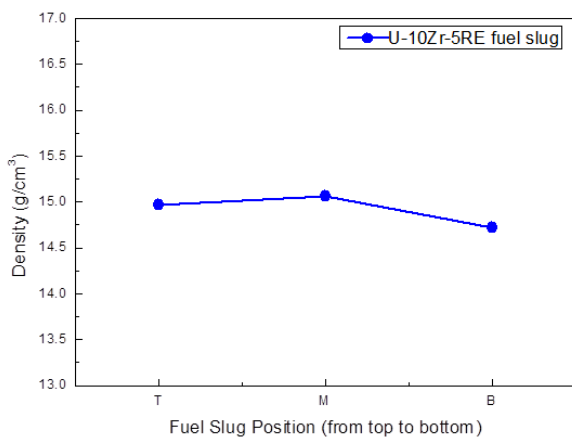


Fig. 3. Density of the recycled U-10wt%Zr-5wt%RE metallic fuel slug

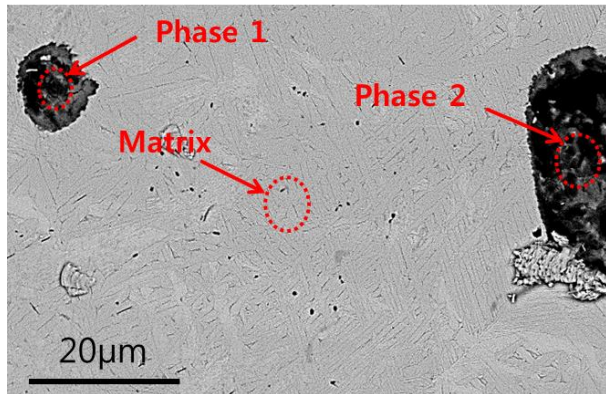


Fig. 4. SEM cross-section image of the recycled U-10wt%Zr-5wt%RE metallic fuel slug

Table I: Composition of phase in U-10wt%Zr-5wt%RE (wt%)

	Phase 1	Phase 2	Matrix
U	2.6	1.2	84.6
Zr	7.0	5.8	15.4
Nd	46.1	44.0	-
Ce	24.0	27.0	-
Pr	14.9	16.8	-
La	5.4	5.2	-

3. Conclusions

To increase the yield rate of the metallic slugs, the recycling of uranium scrap waste is necessary to maximize the uranium resources. In this study, the surface of the heel residue and metallic fuel slugs were polished using a grinding and brushing method. The bulk of the impurity layer was removed except for uranium alloy of a nominal composition. After fabricating the metallic fuel slugs using fuel scraps consisting of the heel residue and unsuitable metallic fuel slugs, U-10wt%Zr-5wt%RE metallic fuel slugs were soundly fabricated. To evaluate the soundness of metallic fuel slugs, density and SEM/EDX analyses were carried out. As a result of the characteristic evaluation, no internal defects were observed. The microstructure was also similarly observed in an SEM cross-section image. Thus, the feasibility of recycling fuel scrap waste was confirmed by fabricating the recycled metallic fuel slugs. In addition, the fuel scrap waste was decreased by recycling the metallic fuel scraps.

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