Fabrication of U-10wt.%Zr Fuel slug for SFR by Injection Casting

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1. Introduction

KAERI seeks to develop and demonstrate the technologies needed to transmute the long-lived transuranic actinide isotopes in spent nuclear fuel into shorter-lived fission products, thereby dramatically decreasing the volume material requiring disposal and the long-term radio-toxicity and heat load of high level waste sent to a geological repository. Metallic fuel has advantages such as simple fabrication procedures, good neutron economy, high thermal conductivity, excellent compatibility with a Na coolant and inherent passive safety [1].

For several decades, the fabrication technology of metal fuel has been developed by various methods such as rolling, swaging, wire drawing, and co-extrusion, but each of these methods had process limitations requiring an additional subsequent process, and needing the fabrication equipment is complex, which is not favorable for remote use. A practical process of metallic fuel fabrication for an SFR needs to be cost efficient, suitable for remote operation, and capable of mass production while reducing the amount of radioactive waste. Injection casting was chosen as the most promising technique, in the early 1950s, and this technique has been applied to fuel slug fabrication for the Experimental Breeder Reactor-II (EBR-II) driver and the Fast Flux Test Facility (FFTF) fuel pins [16,17]. Because of the simplistic nature of the process and equipment, compared to other processes examined, this process has been successfully used in a remote operation environment for fueling of the EBR-II reactor. In this study, vacuum injection casting suitable for remote operation has been developed to fabricate metallic fuel for an SFR

2. Experimental Procedures

Fig. 1 shows the vacuum injection casting system used in this experiment. Depleted lumps of uranium and sponge zirconium were weighed in proportion to the alloy compositions and charged into a melting crucible to fabricate the fuel slugs. Zirconium was fist loaded into the bottom of the graphite crucible followed by U for the U-Zr alloy. The idea was to allow the lower-temperature melting material (U) to flow over and consume the other alloys in an attempt to minimize the material losses. The graphite crucible and quartz molds were coated with high-temperature refractory coating materials to protect against a reaction with the molten uranium alloy. Casting alloys were heated by induction heating at a frequency of 3 kHz and a maximum power of 30kW. When the crucible temperature reached about 200℃ higher than the melting point, it was held and stirred electromagnetically by applying an induction heating cycle from 0% to 100% to ensure the homogeneity of the melt [4-6]. Uranium losses were quantitatively evaluated after casting, and the soundness of the cast samples was measured by gamma-ray radiography. Cast rods were cut into slices of suitable thickness using a slow- speed SiC abrasive cut-off wheel for the metallographic analysis. The density of each location was measured using an Archimedean immersion method. The microstructures and compositions were analyzed using scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX). Chemical analyses were also carried out to confirm the actual compositions of the fuel slugs and other impurities using inductively coupled plasma atomic emission spectrometry (ICP-AES).

Fig. 1. An appearance of the vacuum injection casting apparatus.

3. Results and Discussion

Fig. 2(a) shows U-Zr rods fabricated with a vacuum injection casting system. The surface at the upper region of the slugs was smooth, and the roughness was a little coarse at the lower region where some hot tears were observed. However, the as-cast slugs were generally sound. Gamma-ray radiography of the as-cast metallic fuels was performed to detect internal defects such as cracks and pores, as shown in Fig. 2(b). Internal pores were not detected in the slugs, and thus, the internal integrity of the as-cast slugs was generally believed to be satisfactory. The material balance in the crucible assembly and the mold assembly before and after fabrication of U-10wt.%Zr fuel slug is shown in Table 1. Before casting, the weight of the charged material in the crucible was 584.9 g, and after casting, the weight of the fuel slug was 84.8 g. The residue remaining in the crucible was 499.4 g after casting. Minimum fuel losses after casting relative to the initial charge amount of U-10wt.%Zr fuel slugs were approximately 0.1% which met the proposed goal of less than 0.1% fuel losses during fabrication. It is thought that the low loss is related to melting in a graphite crucible coated with a dense plasma-sprayed high-temperature ceramic material.

Fig. 2. A photo of U-10wt.%Zr fuel slugs fabricated by vacuum injection casting

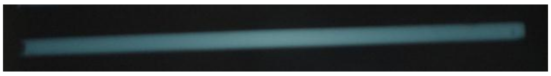

Fig. 3. A gamma radiography of U-10wt.%Zr fuel slugs fabricated by vacuum injection casting

Table 1 Typical material balance after casting of U-10wt.% Zr fuel slugs

	Melting/ Casting part	Weight (g)	Fraction (wt.%)
Before casting	Crucible	584.9	100
After casting	Crucible assembly	499.4	85.4
	Mold assembly	84.8	14.5
Uranium loss		0.7	0.1

4. Conclusions

Vacuum injection casting technique was developed to fabricate metallic fuel for an SFR. The appearance of the fabricated U-10wt.%Zr fuel was generally sound and the internal integrity was found to be satisfactory through gamma-ray radiography. Minimum fuel losses after casting relative to the initial charge amount of U-10wt.%Zr fuel slugs met the proposed goal of less than 0.1% fuel losses during fabrication. Modifications of the current facility system and advanced casting techniques are underway to produce higher quality fuel slugs.

5. Acknowledges

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6. References

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