Melting & Casting Evaluation of Volatile Surrogate U-Zr-Mn Fuel Slugs for SFR

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1. Introduction

The reference fuel for the Korean sodium-cooled fast reactor (SFR) being developed by the Korean Atomic Energy Research Institute (KAERI) is a metallic alloy. Metallic fuel has been studied and is also considered a leading candidate for advanced driver and transmutation fuels under the Fuel Cycle Research and Development (FCRD) program, formerly the Advanced Fuel Cycle Initiative (AFCI) program. The fabrication process for SFR fuel is composed of (1) fuel slug casting, (2) loading and fabrication of the fuel rods, and (3) fabrication of the final fuel assemblies. Fuel slug casting is the dominant source of fuel losses and recycled streams in this fabrication process. These losses and waste streams result in lowering the productivity and economic efficiency of fuel production. Losses occur during mold and crucible interactions, crucible coating infiltration, fuel particle adherence to the mold material and in the case of volatile element-bearing alloys volatilization, in particular, Am. To increase the productivity and efficiency of the fuel fabrication process waste streams must be minimized and fuel losses quantified and reduced to lower levels. Volatile species can be retained through the use of cover gas over pressure, covered crucibles, and short cycle times. In this study, the fabrication method of volatile surrogate U-Zr-Mn fuel slugs for SFR was evaluated in view of the soundness of the fuel slugs and the fuel losses.

2. Experimental Procedure

The elemental lumps of depleted uranium (DU), zirconium, and manganese were used to fabricate U-10wt.%Zr-5wt.%Mn alloy fuel slugs. Graphite crucibles coated with Y_2O_3 and quartz molds coated with ZO_2 was used. The weights of the melting & casting parts and the fuel material before and after melting were measured using an electronic balance. After fabricating a considerable amount of fuel slugs in the casting furnace, the fuel loss in the crucible assembly and the mold assembly have been evaluated quantitatively. After evaluation, the soundness, chemical and microstructural characteristics of the cast fuel slugs were also identified and analyzed.

3. Results and Discussion

The typical material balance in the crucible assembly and the mold assembly after melting and casting of fuel slugs are shown in Table 1. A considerable amount of dross and melt residue remained in the crucible after melting and casting; however, most charged materials were recovered after melting and casting of the fuel slugs.

Table 1. Typical material balance after melting and casting of fuel slugs.

	Melting/casting part	Weight (g)	Fraction (%)
Before melting/ casting	Crucible	1,122.2	100
After melting/ casting	Crucible assembly	67.9	6.1
	Mold assembly	1037.3	92.4

The volatile surrogate U-Zr-Mn fuel slugs were melted and cast with the gravity casting furnace under Ar atmosphere, as shown in Fig. 1. The metal fuel slug had the diameter of 5mm and the length of about 270mm. The alloy composition and the density of the metal fuel slugs were shown in Table 2. It was seen that losses of both of these volatile elements can be effectively controlled to below detectable levels using modest argon overpressures [1-2]. Based on these results there is a high level of confidence that Am losses will also be effectively controlled by application of a modest amount of overpressure.

Scanning electron micrographs of the volatile surrogate U-Zr-Mn alloys melted and cast under vacuum and 760 torr Ar atmosphere were shown in Fig. 2. There were more dendrite dispersion phases compared with U-Zr casting slugs, irrespective of atmospheric pressure. A considerable amount of Mn element was contained in periphery of dendritic dispersions, and eutectic dispersions of 1~2μm in size. The amount of eutectic matrix melted under Ar atmosphere showed much more than melted under vacuum. It means that the U-Zr-Mn alloy melted under Ar atmosphere has higher Mn content than the U-Zr-Mn alloy melted under vacuum.

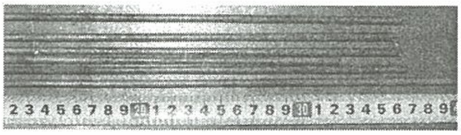
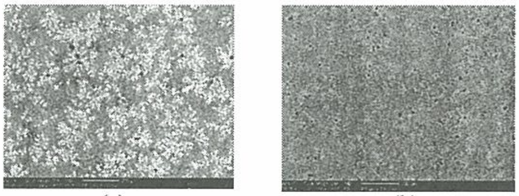


Fig. 1. Typical volatile surrogate U-Zr-Mn fuel slugs, fabricated with the gravity casting furnace under Ar atmosphere.

Table 2. The alloy composition and the density of U-10Zr-5Mn fuel slugs.

Pouring temperature	Zr(wt.%)	Mn(wt.%)	Density(g/cm^3)
1550°C	10.6	5.2	15.6
1650°C	11.9	4.9	16.2



(a) (b)

Fig. 2. Scanning electron micrographs of the volatile surrogate U-Zr-Mn alloys melted and cast under vacuum (a) and Ar atmosphere of 760 torr (b).

4. Summary

The fabrication method of volatile surrogate U-Zr-Mn fuel slugs for SFR was evaluated in view of the soundness of the fuel slugs and the fuel losses. The material balance in the crucible assembly, and the mold assembly after gravity casting of fuel slugs was evaluated quantatively. After evaluation, the chemical and the microstructural characteristics of the cast fuel slugs were also identified and analyzed.

5. Acknowledges

This study was supported the National Nuclear R&D Program of the Ministry of Science and Technology (MOST) of Korea.

6. References

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