Metallic Reactor Fuel Fabrication for SFR

Hoon Song [a*], Jong-Hwan Kim [a], Young-Mo Ko [a], Yoon-Myung Woo [a], Ki-Hwan Kim [a], Chan-Bock Lee [a]
[a]NKorea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, Korea, 305-353
[*]Corresponding author: hsong@kaeri.re.kr

1. Introduction

The Korea Atomic Energy Research Institute (KAERI) seeks to develop a Sodium-cooled Fast Reactor(SFR) fueled with the U-Zr and U-Zr-TRU metal fuel. The metal fuel for an SFR has such advantages such as simple fabrication procedures, good neutron economy, high thermal conductivity, excellent compatibility with a Na coolant, and inherent passive safety[1]. U-Zr metal fuel for SFR is now being developed by KAERI as a national R & D program of Korea. The fabrication technology of metal fuel for SFR has been under development in Korea as a national nuclear R&D program since 2007[2-3]. 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.

In this study, the feasibility of an injection casting method including melting under an inert atmosphere was evaluated in a small-size induction-melting furnace. As experimental equipment, its primary purpose was to explore and define various casting variables, e.g., casting temperature and pressure, pressurizing rate, and mold coating method.

2. Methods and Results

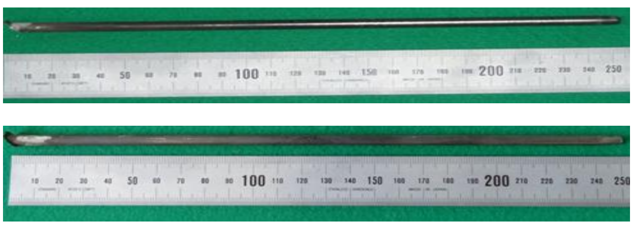
The crucible is inductively heated up to 1600^{o}C, which is sufficiently higher than the liquidus temperature. At a predetermined superheat, the mold was lowered, immersing the open tip into the metal melt. When the metal has solidified, the mold is raised. After cooling, the surrogate fuel slug is taken out of the mold. Graphite crucibles coated with a high-temperature ceramic plasma-spray coating method and quartz molds coated with a high-temperature ceramic by a slurry-coating method were used. After fabricating the fuel slugs in a casting furnace, the fuel losses in the crucible assembly and the mold assembly were quantitatively evaluated. The soundness, and chemical composition, and density of the as-cast fuel slugs were identified and analyzed. The soundness of fuel slugs was inspected by using gamma-ray radiography to evaluate the feasibility of the fabrication method.

The densities of the fuel slugs were also measured using an Archimedean immersion method. A scanning electron microscope (SEM) was used to study the microstructure of as-cast fuel slugs. Chemical compositions of as-cast the fuel slugs were measured by through energy-dispersive spectroscopy (EDS). Metal fuel slugs were then examined with casting soundness and density.

Metal fuel slugs with a diameter of 5mm and a length of 250 mm were fabricated using an injection casting, as shown in Fig. 1. The general appearance of the metallic fuel slugs was smooth and the roughness was a little coarse at the lower region. Gamma-ray radiography was performed to detect internal defects such as cracks and pores inside the metal fuel slugs. The typical material balance in the crucible assembly and mold assembly after fabrication is shown in Table 1. A considerable amount of dross and melt residue remained in the crucible after melting and casting; however, most charge materials were recovered after fabrication of the fuel slugs. The alloy compositions of U-10wt.%Zr fuel slugs are shown in Table 2. The Zr content in the U-Zr fuel slugs at 8 axial positions (3 positions in the upper part of slug fuel, 3 positions in the middle part, and 2 positions in bottom part) showed a little deviation within range of 0.1% to 0.3%, hence it can say that alloy was casted uniformly. The total amount of impurities (O, C, Ni, Si) was lower than the limit: 5,000 ppm.

Table 1: Material Balance after U-10wt.%Zr fuel slugs.

구분		No. 1		No. 2		No. 3		No. 4	
	Casting part	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)
Before casting	Crucible	U:488.15 Zr:57.34	100	U:458.28 Zr:53.71	100	U:461.71 Zr:54.17	100	U:478.08 Zr:56.08	100
After casting	Crucible	459.59	84.25	420.26	82.12	429.13	83.18	448.65	83.99
	Mold assembly	85.44	15.66	85.97	16.79	85.62	16.6	84.9	15.89
Fuel loss		0.46	0.08	5.56	0.97	0.33	0.06	0.05	0.01



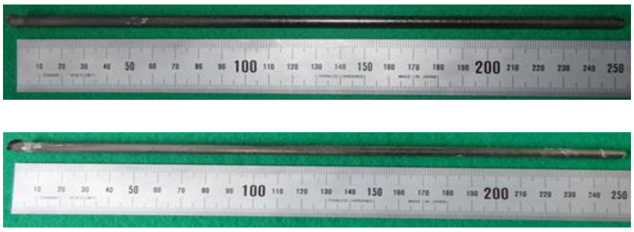


Fig. 1. U-10wt.%Zr metallic fuel fabricated by injection casting with a varied process parameters.

Table 2: Alloy Composition of U-10wt.%Zr Fuel Slugs Prepared by Injection Casting Method.

Position		U	Zr	Si	C	H	O	N
Upper	1	90.1	10.3	<0.005	50	4	590	20
	2	89.2	10.6	<0.005	110	3	540	20
	3	90.2	10.4	<0.005	90	15	540	20
Middle	1	90.5	9.94	0.05	70	7	530	10
	2	90.5	9.73	0.02	190	3	540	10
	3	90.9	9.9	0.03	20	3	680	10
Bottom	1	90.6	10.1	0.05	20	6	850	10
	2	90.2	10.3	0.05	30	6	1130	20

3. Conclusions

Fabrication on the rod type metallic fuel was carried out for the purpose of establishing a practical fabrication method. Rod-type fuel slugs were fabricated by injection casting. Metallic fuel slugs fabricated showed a general appearance was smooth. Through the quality test, it was confirmed that fuel slugs of high quality can be fabricated with reasonable throughout.

REFERENCES

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