Preliminary Tests of Engineering-Scale Injection Casting for SFR

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1. Introduction

Metallic fuels, such as the U-Pu-Zr alloys, have been considered as a nuclear fuel for a sodium-cooled fast reactor (SFR) related to the closed fuel cycle for managing minor actinides and reducing the amount of highly radioactive spent nuclear fuels since the 1980s. Metallic fuels fit well with such a concept owing to their high thermal conductivity, high thermal expansion [1,2]. For the development of manufacturing process for U-Pu-Zr fuel, we had developed the engineering-scale injection equipment following the laboratory scale. In this study, engineering-scale injection casting tests were conducted to find the practical quality of the fuel slugs and confirm that the reasonable throughout will be attained when the engineering scale equipment is used.

2. Methods and Results

In this section experimental methods and results are described.

2.1 Experiment Procedure

KAERI(Korea Atomic Energy Research Institute) had prepared the engineering-scale injection casting equipment (Fig. 1). The engineering-scale injection casting tests with Cu were repeated eight times (Table 1), and 474 Cu slugs were produced. The injection casting system was used in this experiment. Injection casting uses the pressure difference between the mold's interior and the furnace's gas pressure to drive the molten metal up into the quartz tube. Graphite crucibles and quartz molds were 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. The Cu castings were taken out of the molds after cooling them to room temperature. The diameter of the Cu slugs was measured at 3 axial points: top, middle, bottom, measured in two perpendicular directions at each axial position. The weight of the slug was measured with an electronic balance. The density of the slug was calculated from the average diameter and weight. After measuring, the RT test was performed to find the sound part of the slug and both ends of the slug was cut off and 300mm long Cu slugs were obtained. After that, the real density was measured using an Archimedean immersion method. The diameter and weight was measured again to calculate the density to make a comparison between the real density and the calculated density.

2.2 Results

The fuel slug specification consistent with the practical reactor core design was previously set as the average diameter precision ± 0.05mm, density satisfying within 96% of theoretical density, total impurities (O, C, N, Si) less than 2,000 ppm. The specification was satisfied in a series of engineering-scale tests. Figure 2 shows one of Cu slugs obtained in the tests. Typical distribution of the slug diameter and density are presented in Fig. 3 and 4, respectively. The residual metal in the crucible (heel) and both ends of casting (scrap) will be reused as the metal charge for the subsequent use in the practical fuel fabrication process. The total amount of impurities (O, C, N, Si) was still lower than the provisional limit: 2,000 ppm.

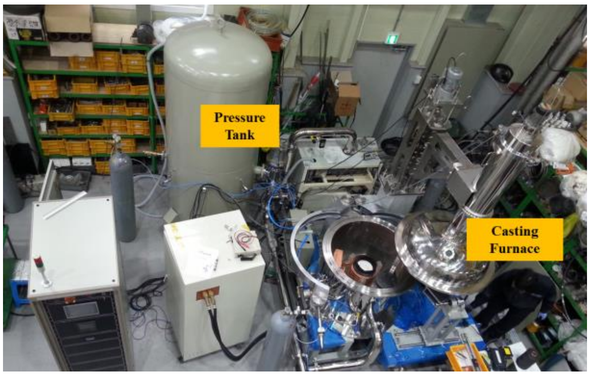

Fig. 1. Engineering-scale injection casting equipment (Max. U-Zr charge: 20kg, installed at KAERI

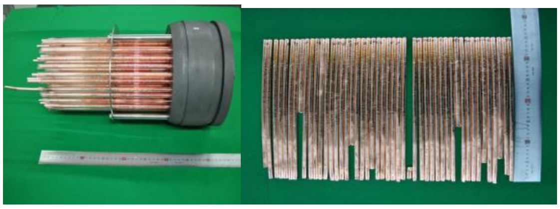

Fig. 2. Mold bundle after casting(left) and Cu slug after mold removal(right)

Table 1. Conditions and resulting casting ratio of the tests

Test #	#1	#2	#3	#4
Initial charge (kg)	8.70	9.97	4.70	4.50
Number of molds	48	78	12	24

Length of molds (mm)	*400*	*400*	*450*	*450*
Pressure before injection (Torr)	*400*	*400*	*400*	*600*
Molten metal temp. at injection (℃)	*1,180*	*1,205*	*1.196*	*1,193*
Pressurization rate(bar/sec)	*1.5*	*1.5*	*2.19*	*2.5*
Casting ratio (%)	*56*	*69*	*20*	*39*

Test #	#5	#6	#7	#8
Initial charge (kg)	*9.66*	9.97	9.65	9.89
Number of molds	*78*	78	78	78
Length of molds (mm)	*450*	*450*	*450*	*450*
Pressure before injection (Torr)	*0*	400	400	400
Molten metal temp. at injection (℃	*1,216*	1,182	1,214	1,215
Pressurization rate(bar/sec)	*1.5*	*1.5*	*2.19*	*2.5*
Casting ratio(%)	*72*	*55*	*68*	*57*

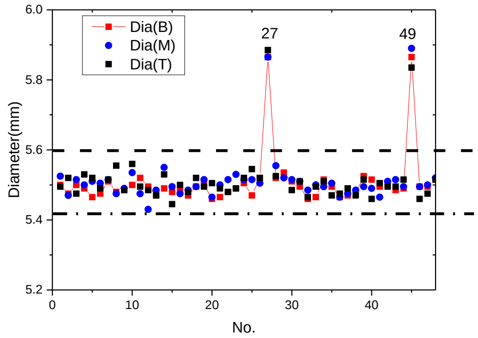

Fig. 3. Typical distribution of the slug diameter

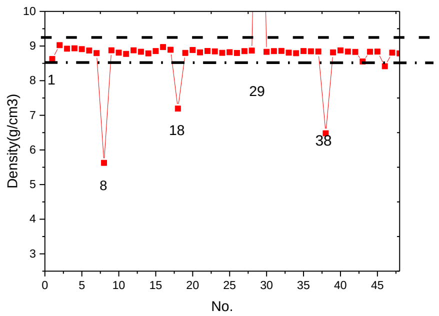

Fig. 4. Typical distribution of the slug density

3. Conclusions

Most of the Cu slugs fabricated in the engineering-scale injection casting tests satisfied the practical specifications determined provisionally, except for test #6 that is estimated to be casted under low temperature. The injection casting technology will be applicable to the commercialized fuel cycle after the laboratory-scale injection casting test conducted for confirmation of the practical quality of the U-Pu-Zr fuel slug. The reasonable casting ratio was obtained in the reasonable ratio 72% during tests through the optimization of the depths of the mold bottom end in the molten fuel.

REFERENCES

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[2] H.F. Jelinek, G.M. Iverson, Equipment for Remote Injection Casting of EBR-II Fuel, Nucl. Sci. Eng., Vol.12, p.405, 1962.