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Engineering Scale Remote Injection Metal Fuel Slug Manufacturing

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1. Introduction

Metallic fuels, such as the U-Pu-Zr alloys, have 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]. Because all the manufacturing process performed in hot cell facility due to high radiation material of recycled nuclear fuel, it is important to develop the remote fabrication technology. For the development of manufacturing process for U-Pu-Zr fuel, we had developed the engineering-scale remote injection equipment following the laboratory scale. In this study, engineering-scale remote injection casting tests conducted to find the practical quality of the fuel slugs and confirm that the reasonable throughout will attained when the engineering scale equipment is used.

2. Methods and Results

2.1 Experiment Procedure

KAERI(Korea Atomic Energy Research Institute) had prepared the engineering-scale remote injection casting equipment (Fig. 1). The engineering-scale injection casting tests with Cu and Cu-Ni repeated many times before uranium casting test to find the proper casting process parameters such as melting batch, melt casting temperature, mold preheating time, and melt deposition time selected to produce the sound fuel slug. After that, engineering scale 78 U-Zr fuel slugs casting test performed. Table 1 shows the casting conditions used in the engineering test. The injection casting method used in this experiment uses the pressure difference between the mold's interior and the furnace's gas pressure to drive the molten metal up into the quartz mold tube. Graphite crucibles and quartz molds used during casting. The crucible increased the temperature to 1600 degrees above the liquid temperature of the U-Zr material. All work performed in the argon atmosphere. Melting process started by induction heating using the power generator. When the desired molten metal injection temperature reached, the mold assembly lowered using the mold-lifting device, the mold assembly lowered into the crucible, and the end of the mold assembly inserted into the molten metal. When the molten metal in the mold solidified, the mold assembly lifted up. The weights of the melting & casting parts and the fuel material before and after melting 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 evaluated quantitatively. The U castings taken out of the molds after cooling them to room temperature. The diameter of the fuel slugs was measured at 3 axial points: top, middle, bottom, measured in two perpendicular directions at each axial position. The density of the slug calculated from the average diameter and weight. After measuring, the RT test performed to find the sound part of the slug. Both ends of the slug cut off and sound slugs obtained. After that, the real density measured using an Archimedean immersion method. The diameter and weight 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, 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 U-Zr fuel slugs obtained in the tests. Typical distribution of the slug diameter and weight presented in Fig. 3 and 4, respectively. The residual metal in the crucible (heel) and both ends of casting (scrap) will reuse 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.

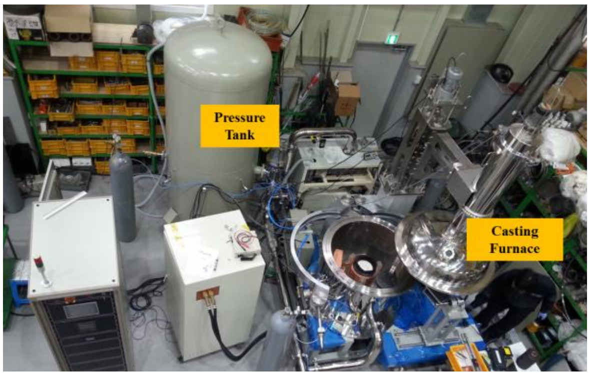

Fig. 1. Engineering-scale injection casting equipment (Max. U-Zr charge: 20kg, installed at KAERI

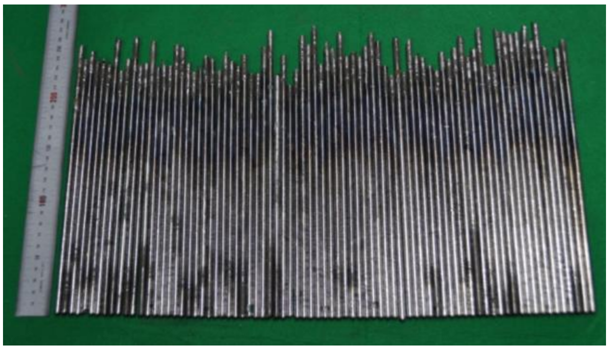

Fig. 2. U-Zr fuel slug after mold removal

Table 1. Casting conditions of the test

Conditions	*Value*
Initial charge (kg)	*16.4*
Number of molds	*78*
Length of molds (mm)	*450*
Pressure before injection (Torr)	*400*
Molten metal temp. at injection (℃)	*1,550*
Pressurization rate(bar/sec)	*2.81*

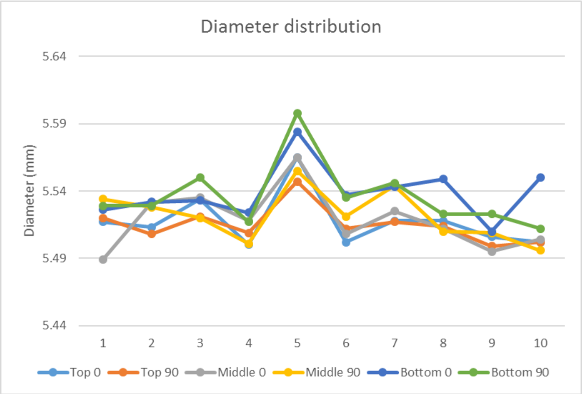

Fig. 3. Typical distribution of the slug diameter

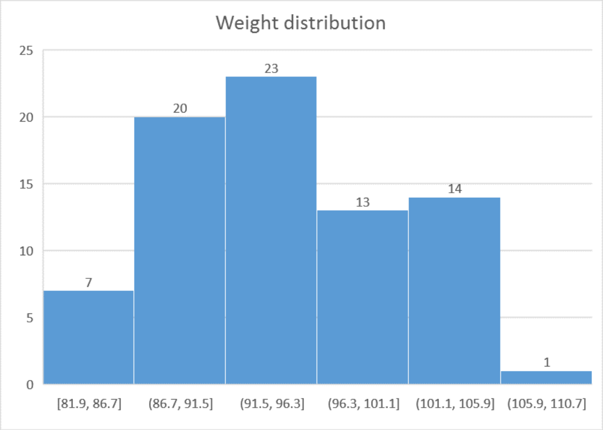

Fig. 4. Typical distribution of the slug weight

3. Conclusions

U-Zr metal fuel slugs fabricated by performing remotely casting test to verify the feasibility of manufacturing a fuel slug using remote engineering-scale metal fuel fabrication equipment for manufacturing a recycled metal fuel slug in a hot cell. After the casting test, it was confirmed that 78 U-Zr fuel slug, which is the maximum fuel slug in the batch, were made remotely and soundly.

REFERENCES

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