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Modified Injection Casting for Preventing the Evaporation of Volatile Elements

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has sought 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. Although an injection casting has been a well-established fabrication method for metal fuel for decades [1], Am addition to the metal fuel hampers conventional fuel fabrication processes because of the high vapor pressure of Am at melting temperature of uranium alloys [2]. An advanced fuel casting system to control transport of volatile elements during melting of a fuel alloy with minor actinides (MA) has been developed. It is necessary to minimize the vaporization of Am and volume of radioactive wastes [3].

In this study, advanced fuel slug fabrication methods have been introduced to develop an innovative fabrication process of metal fuel of SFR for preventing the evaporation of volatile elements such as Am. Metal fuel slugs were fabricated by improved injection casting method in KAERI. Fuel slugs for SFR were characterized to evaluate the feasibility of the alternative fabrication method.

2. Methods and Results

The feasibility of improved injection casting method including melting under inert atmosphere was evaluated using a small-size induction-melting furnace. As experimental equipment, its primary purpose was to explore and define various injection casting variables, e.g., casting temperature and pressure, pressurizing rate, mold coating method. Pure cupper was selected as a surrogate material, which has a melting temperature similar to uranium. All operations were done under argon atmosphere. At a predetermined superheat, the mold was lowered, immersing the open tip into the metal melt. When the metal has solidified, the mold was raised. After cooling, the surrogate fuel slug is taken out of the mold. As-cast fuel slugs were inspected by gamma-ray radiography. An optical microscope (OM) was used to study the microstructure of as-cast fuel slugs.

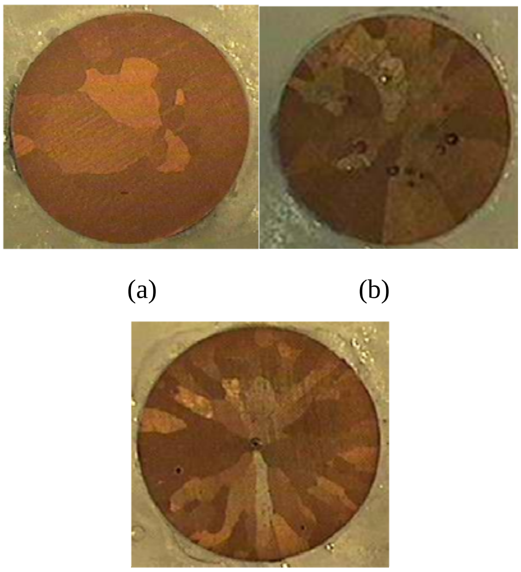
As shown in Fig. 1-(a) a surrogate fuel slug was soundly cast by improved injection casting method, melted surrogate material under inert atmosphere. The general appearance of the slug was smooth and the length was about 250mm. Some hot tears were observed in the upper part region, resulting from quick cooling. It was thought that this area of a casting was not allowed to shrink quickly, placing the area under tension from metal contraction near the solidus temperature of the alloy. Contraction of the metal between the fronts above the solidus temperature tore away from the solidified casting. The gamma-ray radiography of as-cast surrogate slug was performed to detect internal defects such as cracks and pores, as shown in Fig. 1-(b). Propagation of the solidification front occurred toward the thermal center of the casting and grain growth simultaneously occurred in the partially liquid portion of the casting, which creates an increasing resistive path for molten metal to flow. The pores detected in the upper part region were expected to occur in areas of the casting where grain growth starved the shrinkage areas of molten metal. This kind of defect becomes much more evident and challenging to overcome with increasing alloying element contents in fuel alloy, as the freezing range continues to widen. In order to control the void created by microshrinkage, it was judged to increase the pressure during casting and cooling, which effectively increases the feeding distance resulting in reducing the number and size of gas pores that are trapped at grain boundaries and, therefore, allowing an extended nucleation and growth process [4]. However, the internal integrity of as-cast metal fuel slugs in the lower part was generally satisfactory.

(a)

(b)

Fig. 1. Typical surrogate fuel slug (a) and gamma-ray radiography (b), fabricated with the improved injection casting process under inert atmospheric pressure.

Optical micrographs of the surrogate fuel slug cast according to solidifying position are shown in Fig. 2. The grain size was seen to increase from lower position to upper position. This is because the solidification rate at the upper position, where molten melt solidifies first, is very high compared to at a lower position.



(a) (b)

(c)

Fig. 2. Optical micrographs of the surrogate fuel slug cast according to solidifying position; (a) lower position, (b) middle position, (c) upper position.

3. Conclusions

In order to prevent the evaporation of volatile elements such as Am, alternative fabrication method of metal fuel slugs has been applied and evaluated by improved injection casting method, melted fuel material under inert atmosphere, instead of vacuum injection casting method in KAERI. Surrogate fuel slugs were generally soundly cast with the adjustment of casting process parameters by the modified injection casting method.

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