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Fabrication of Reduced Metallic Fuel Elements for SFR Fuel Irradiation in the HANARO

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1. Introduction

KAERI seeks 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. . Metallic fuel has 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-Pu alloy fuels have been used for sodium-cooled fast reactor (SFR) related to the closed fuel cycle for managing minor actinides and reducing a high radioactivity levels since the 1980s.

Fabrication technology of metallic fuel for SFR is being developed in Korea as a national nuclear R&D program from 2007 [2-5]. The irradiation test of U-Zr and U-Zr-Ce fuels in the HANARO has been planned to evaluate irradiation capsule integrity and to validate in-reactor barrier performance. The reduced fuel elements of U-Zr and U-Zr-Ce fuels have been fabricated for the irradiation test of SFR fuel in the HANARO since 2009. Process flow diagram of reduced metallic fuel element is shown in Fig. 1. The fabrication of the reduced fuel elements will be reported in this paper.

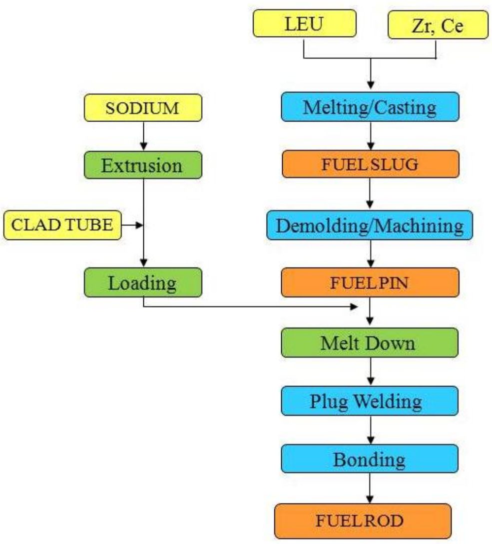

Fig. 1. Process flow diagram of reduced metallic fuel element.

2. Methods and Results

2.1 Fabrication of reduced metal fuel slugs

The reduced metal fuel slugs were cast using low-enrichment uranium (LEU) with the gravity casting furnace under Ar atmosphere, as shown in Fig. 2. The metal fuel slug had the diameter of 4.2mm and the length of about 150mm. The alloy composition and the density of the metal fuel slugs were shown in Table 1. Scanning electron micrographs of the fuel slugs were shown in Fig. 3. U-10wt.%Zr fuel slug had some dispersion phases of Zr precipitates and Zr compounds, and U-10wt.%Zr-Ce fuel slug had lots of dispersion particles including Ce component. After casting the metal fuel slugs, the fuel slugs were machined into the pin of 3.6mm in diameter and 50mm in length by a lath.

Fig. 2. Typical metal fuel slugs cast by gravity casting method under Ar atmosphere.

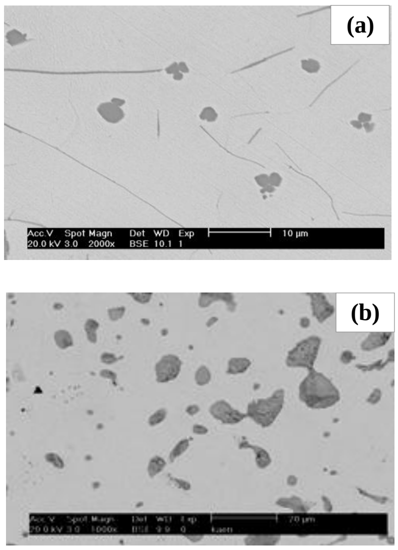

Fig. 3. Scanning electron micrographs of the fuel slugs; (a) U-10wt.%Zr, (b) U-10wt.%Zr-Ce.

Table 1. Alloy composition and density of metal fuel slugs.

Nominal Composition	Zr(wt.%)	Ce(wt.%)	Density(g/cm^3)
U-10Zr	7.9	-	16.0
U-10Zr-Ce	9.3	1.9	14.2

2.2 Fabrication of reduced fuel elements

Sodium loading and settling were carried out in Ar atmosphere glove box. A sodium wire and a reduced fuel slug were subsequently loaded into a jacket. Upto 3 reduced fuel rods were loaded into a settling furnace, heated to above 200^{o}C, and held at this temperature to settle the fuel slugs into the molten sodium within the jackets. Settled fuel rods were removed to a cooling plate for a minimum of 10min.

The fuel rods were closed by insertion and welding of the end plugs. After electron-beam welding, the claddings were checked visually, and examined in microstructure and mechanical properties, resulted in establishing optimum welding conditions for the jacket. The plugs of the fuel elements were welded with the optimum welding parameters under vacuum by an electron beam welding equipment.

Sodium bonding is the process of wetting sodium to the fuel slug and cladding and removing any voids present in the annulus (the region between the fuel slug and cladding), each of which ensures adequate heat transfer between the fuel and cladding The lower end of the fuel rod in the bonder magazine rested on impact plunger. The bonder magazine was bonded at about 500^{o}C. Fuel rod displacement was set to a specific range to provide necessary amount of energy for sodium bonding without damaging the rod. Thus, the reduced fuel elements of U-10wt.%Zr and U-10wt.%Zr-Ce fuels have been fabricated for the irradiation test of SFR fuel.

3. Conclusions

The reduced metal fuel slugs were cast using low-enrichment uranium (LEU) with the gravity casting furnace under Ar atmosphere. Sodium settling and bonding were carried out with sodium furnace in Ar atmosphere glove box. The plugs of the fuel elements were welded with the optimum welding parameters under vacuum by an electron beam welding equipment. Hence, the reduced fuel elements have been soundly fabricated for the irradiation test of SFR fuel in the HANARO.

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