Engineering-Scale Development of Injection Casting Technology for Metal Fuel Cycle

Background

The metal fuel concept, which enhances the core performance of sodium-cooled fast reactors, utilizes the U-Pu-Zr alloy rod as a fuel body. This alloy rod, called 'fuel slug,' is fabricated by the injection casting shown in Fig.1. The simplicity of the injection casting process is expected to reduce the cost of fast reactor fuel fabrication. CRIEPI had prepared the engineering-scale injection casting equipment (Fig.2) and shown that longer (>400 mm) and thicker (>~6 mm in diameter) U-Zr slugs can be fabricated. In order to clarify the applicability of the injection casting technology to the commercialized fast reactor fuel cycle, it should be confirmed that fuel slugs of sufficiently high quality can be fabricated with reasonable throughput.

Objectives

To show that fuel slug quality is consistent with the practical reactor core design and fuel fabrication process, confirm that the throughput of the casting is reasonable, and demonstrate that the injection casting technology is applicable to the commercialized fast reactor fuel cycle.

Principal Results

The engineering-scale injection casting tests with U-Zr alloy were repeated ten times, and 500 U-Zr slugs were produced. The practical quality of the fuel slugs and the reasonable throughput were attained, as described below. As a result, applicability of the injection casting technology to the commercialized fuel cycle was demonstrated.

1. Fuel slug quality

The fuel slug specification consistent with the practical reactor core design was provisionally set as the average diameter precision ±0.05 mm, local diameter precision ±0.1 mm, density 15.3 ~ 16.1 g/cm^3 and zirconium content 10 ±1 wt%. This specification was satisfied in a series of engineering-scale tests. Figure 3 shows one of the U-Zr slugs obtained in the tests. Typical distributions of the slug diameter and density are presented in Fig.4 and 5, respectively.

The residual metal in the crucible (heel) and both ends of casting (scrap) were reused as the metal charge for the subsequent test, simulating the practical fuel fabrication process. The total amount of impurities (O, C, N, Si) was still lower than the provisional limit: 2000 ppm.

Although 1.1% Mo, 0.8% Pd, 0.06% Ce and 0.1% Nd were added to the metal charge, simulating the fission product elements that may remain in the pyroprocess products, the precipitations of these elements were not detected in the U-Zr slugs.

2. Throughput

The reasonable throughput of the process required that the casting ratio (weight percent of injected metal to charged metal) be increased. The optimization of the depth of the mold bottom end in the molten fuel, the molten fuel covering of the mold bottom end opening at injection completion and the array pattern of mold bundle resulted in the reasonable casting ratio 70% to 80%.

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Future Developments

Laboratory-scale injection casting tests will be conducted for confirmation of the practical quality of the U-Pu-Zr fuel slug.

Main Researcher: Takanari Ogata, Ph. D.,
Senior Research Scientist, Advanced Nuclear Fuel Cycle Sector, Nuclear Technology Research Laboratory

Reference

Progress Reports of MEXT Innovative Nuclear Technologies Program, "Development and Improvement of Electrometallurgical Process," 2002, 2003, 2004, 2005 (in Japanese).

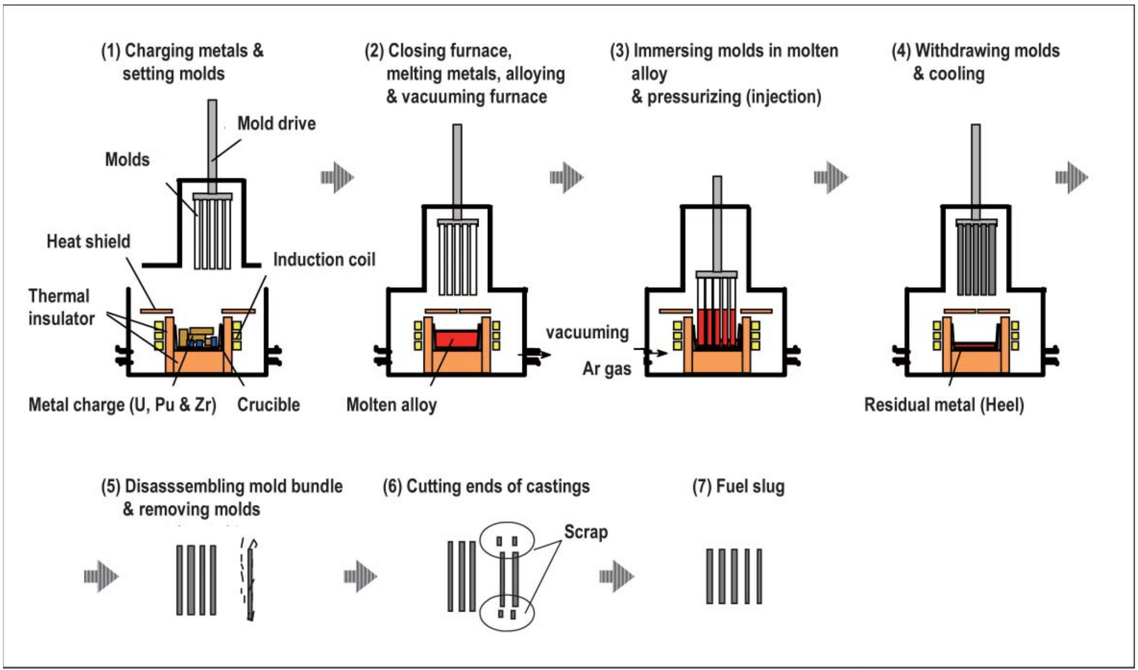

Fig.1 Outline of injection casitng process

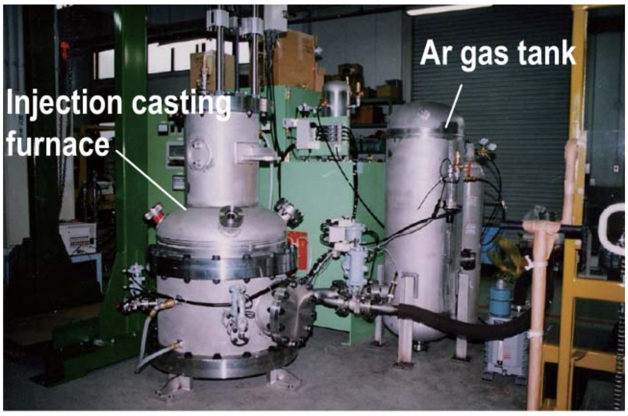

Fig.2 Engineering-scale injection casting equipment (Max. U-Zr charge: 20 kg, installed at Nuclear Fuel Industry Inc., Tokai)

Fig.3 Mold bundle after casting (left) and U-Zr slug after mold removal (right)

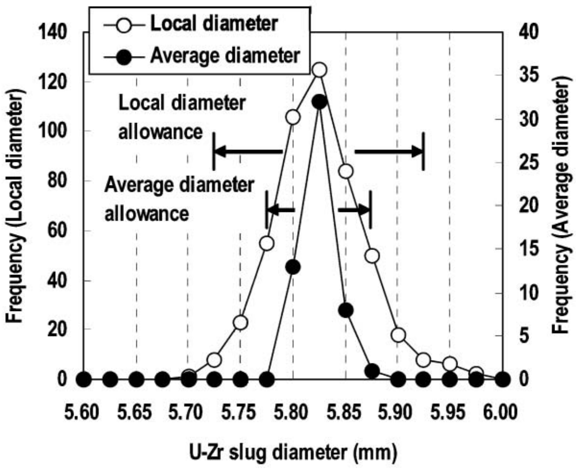

Fig.4 Typical distributions of the slug diameter

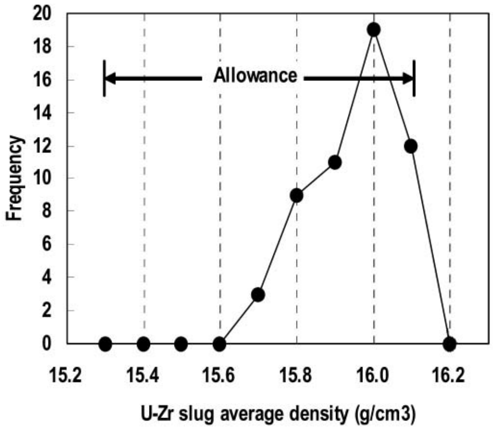

Fig.5 Typical distribution of the slug density