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# Fabrication and Quality Inspection of U-10wt.%Zr Fuel Rod for Irradiation Test

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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 [1-3]. 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.

Metal fuels such as U-Zr alloy have been considered as a starting driver fuel for a proto-type Gen-IV sodium-cooled fast reactor (PGSFR) in Korea. To confirm the design and fabrication technologies of metallic fuels with FMS cladding for the loading of metallic fuel in PGSFR, an irradiation test will be performed in BOR-60 in Russia in 2016. In this study, U-10wt.%Zr fuel rods using low enrichment uranium (LEU) have been fabricated and inspected in quality for the fuel verification of PGSFR.

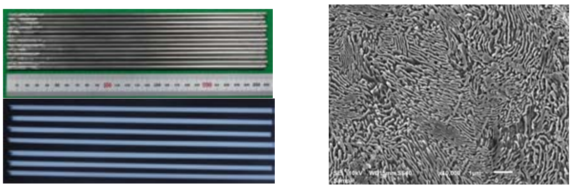
## 2. Methods and Results

### *2.1 Fuel Slug Fabrication*

For fabrication of SFR metallic fuel slugs for the irradiation test, the injection casting method was applied in the modified induction melting furnace. The optimum casting conditions were established by repeated experiments on casting process parameters such as casting temperature, pressure, pressurizing rate, and mold coating conditions. Based on the selected casting conditions, the optimized casting process was performed. Consequently, U-10wt.%Zr fuel slugs without casting defects were fabricated by development of the advanced casting technology and evaluation tests. As a result of qualified tests, the quality of fuel slugs for the irradiation test was verified.

### *2.2 Sodium Bonding*

Integrated operation and safety condition of the sodium filling/melting/bonding process were established to fabricate metallic fuel rod. The enhanced process consists of four steps: charging sodium and fuel slug into the cladding tube, top-end plug welding, melting down the sodium metal, and bonding the materials in the fuel rods. Analysis and evaluation techniques such as defect and pore verification, sodium level check, slug position check and measuring procedure were also accomplished. Moreover, an extruding machine for sodium, charging equipment, and components of equipment were designed and produced to develop the SFR sodium handling technology. The enhanced evaluation technology significantly increased the yield of inspection results.



(a) (b)

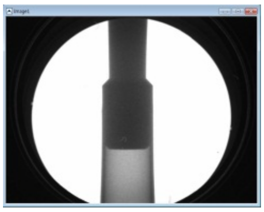
Fig. 1. LEU-10wt.%Zr fuel slugs fabricated by injection casting: (a) images of fuel slugs, (b) gamma-ray radiography.

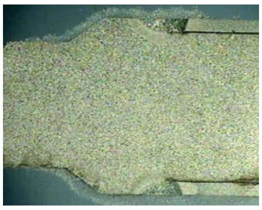
Fig. 2. X-ray radiography image for sodium defect inspection (fuel slug position, sodium level, and top-end plug check; from left to right).

### *2.3 End Plug Welding*

The gas tungsten arc welding (GTAW) technology was adopted and the welding joint design was improved to fabricate the metallic fuel rods. The optimal welding conditions and parameters were also established through lots of experiments. The end plug welding of the SFR metallic fuel rod is a special process and the welding quality should be verified through the qualification test according to the Quality Assurance Program (QAP) and the regulation Korea Electric Power Industry Code (KEPIC). Based on the developed welding technology, welding equipment, welding conditions and parameters, the qualification test carried out to prove the weld quality of end plug welding of the metallic fuel rods. According to the qualification test plan and procedures, the weld quality evaluation tests were conducted and verified the weld quality of end plug welding. On the basis of qualification results, SFR metallic fuel rods for the irradiation test were successfully manufactured with satisfying the Inspection and Test Plan (ITP) under the QAP.

(a)

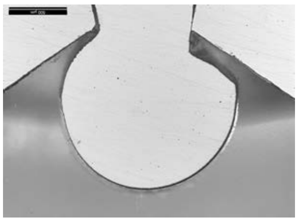




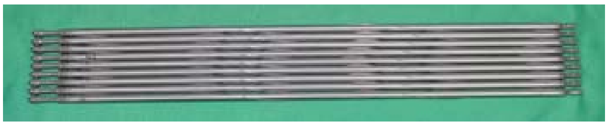
(b) (c)

Fig. 3. (a) Fuel rods welded by GTAW, (b) X-ray radiography result on the weld part, and (c) metallographic examination on the weld part.

*2.4 Wire Wrapping*



(a) (b)



(c)

Fig. 4. (a) Microstructure image of a fusion ball, (b) ruptured region after tensile test, and (c) wire wrapped rods for the irradiation test.

The HT9 wire was used to wrap the metallic fuel rods. Two kinds of wires were wrapped on the fuel rods by wrapping machine and welded by the GTAW. Wrapping parameters and conditions such as fusion ball diameters, ball locations and pitch sizes were controlled to satisfy quality requirements. The wires were inspected by tensile test and wrapping conditions were also analyzed by residual tension test. The wire wrapping of fuel rods for the irradiation test was accomplished successfully.

## 3. Conclusions

The injection casting method was applied to metallic U-10wt.%Zr fuel slugs having the diameter of 5.5mm. Consequently, fuel slugs per melting batch without casting defects were fabricated by development of the advanced casting technology and evaluation tests. The optimal GTAW welding conditions and parameters were also established through lots of experiments. And, the qualification test carried out to prove the weld quality of end plug welding of the metallic fuel rods. The wire wrapping of metallic fuel rods for the irradiation test was successfully accomplished in KAERI. So, PGSFR fuel rods for the irradiation test in BOR-60 have been soundly fabricated in KAERI.

## ACKNOWLEDGEMENTS

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