# Qualification Test of End Closure Welding for SFR Metallic Fuel Rod

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## 1. Introduction

The Gen-IV program was started by eleven countries from 2000 for the development of innovative nuclear energy system with the goals, safety, economics, resource utilization, waste management, proliferation resistance and physical protection (PR&PP) [1]. The sodium-cooled fast reactor (SFR) system is among the six systems selected for Gen-IV promising systems and expected to be deployed in 2020. In Korea, the R&D on a sodium-cooled fast reactor (SFR) has been begun since 1997, as one of the national long-term nuclear R&D programs. As a fuel for SFR, metallic fuel, U-Zr alloy fuel, was selected and is being developed. And also the international collaborative research is under way on U-TRU-Zr fuel developments with the closed fuel cycle of full actinide recycling, within Advanced Fuel Project for international generation IV (Gen-IV) SFR.

For the fabrication of SFR metallic fuel rods, the end plug welding is a crucial process [2,3]. The sealing of end plug to cladding tube should be hermetically perfect to prevent a leakage of fission gases and to maintain a good reactor performance [4]. In this study, the qualification test of the end closure welding for SFR metallic fuel rods was carried out based on the developed welding technique, welding equipment, welding conditions and parameters [5]. Through the qualification test, the end closure welding of SFR metallic fuel rods were well proved.

## 2. Characteristics of SFR metallic fuel

Fig. 1 shows the specifications and dimensions of SFR metallic fuel assembly which is under development at KAERI. The composition of the fuel is U-20%TRU-10%Zr for the closed fuel cycle and U-10%Zr for a prototype reactor. As shown in this figure, a fuel assembly is composed of a nose piece and a handling socket at the both ends, and a hexagonal duct in the middle part which contains 217 fuel rods assembled inside it [6]. Each fuel rod has a lower end plug, a fuel slug, an upper gas plenum, and an upper end plug as shown in Fig. 1. The outside of fuel rod is wrapped with a wire. In inside of fuel rod, the gap between fuel slug and fuel cladding is filled with sodium (Na). In principle, a closed fuel cycle is based on recycling spent fuel discharged from pressurized water reactor, which means the handling of high radioactive materials. Since americium (Am) is a strong gamma emitter, and curium (Cm) a high neutron emitter, the fabrication of TRU bearing metallic fuel needs to be performed in a remote control fabrication facility in a shielded hot-cell with sufficient radiation protection. Moreover, all the fabrication works should be performed in an inert atmosphere, because of the high reactivity of the handling materials like Uranium (U), Plutonium (Pu), and Sodium (Na) metals.

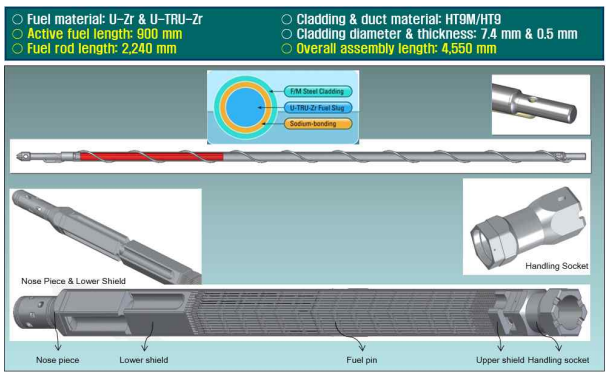


Fig. 1 SFR metallic fuel

## 3. End Closure Welding

There are many commercialized welding techniques such as GTAW, electron beam welding (EBW), and laser beam welding (LBW) as a sort of fusion welding and resistance upset butt welding, percussion welding, and flash welding as a sort of solid state welding. Among them, a resistance upset butt welding is now used for the end plug welding of PWR fuel elements and CANDU fuel rods in a commercial basis. The end plug welding method should be selected and developed in consideration of weldability, weld joint design, production efficiency, etc. For end closure welding of SFR metallic fuel rod, the welding technique, welding equipment, welding conditions and parameters were developed. The GTAW technique was adopted and the welding joint design was improved. And the optimal welding conditions and parameters were well established as reported before [2,3,5].

## 4. Qualification Test

### *4.1 Qualification test plan*

The end closure welding of SFR metallic fuel rod is a special process according to the Quality Assurance Program and the regulation KEPIC (Korea Electric Power Industry Code). Thus, the qualification test has to be done to prove the weld quality of end closure welding of SFR metallic fuel rod. The following qualification test plan and procedures were developed.

- Welding 20 dummy fuel elements by GTAW
- Visual inspection
- X-ray radiography
- Selecting 10 elements for quality evaluation
- He- leak test for 5 elements
- Measuring dimensions for 5 elements
- Analyzing the gas contents purity
- Metallographic examination for 3 elements
- Burst test for 3 elements
- Tensile test for 3 elements

*4.2 Qualification test results*

Based on the developed welding technique, welding equipment, welding conditions and parameters [5, 6], 20 dummy rods were prepared with the following welding parameters.

- Stick-out : 0.7 mm
- Weld current : 30A
- Rotation speed : 30 rpm

Fig. 2 Dummy fuel rods welded by GTAW

According to the qualification test plan and procedures, the weld quality evaluation tests were conducted and the following test results were obtained.

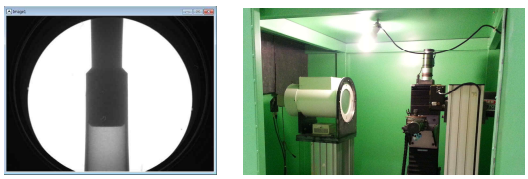

Fig. 3 X-ray radiography result on the weld part

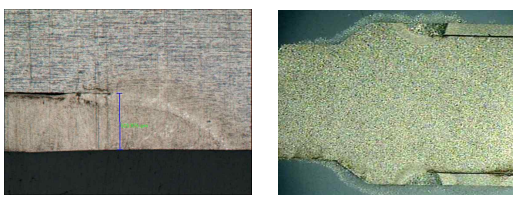

Fig. 4 Metallographic examination result on the weld part

Fig. 5 Burst test result

Fig. 6 Tensile test result

As shown in Fig. 2-6, the results of visual inspection, X-ray radiography, metallographic examination, burst test and tensile test satisfied the requirements on the weld. And also it was not found any defects in a helium leak test and a dimension measurement. The helium gas filled in an inner space of fuel rod was analyzed by Gas – Mass Spectrometry. It showed 99.625 %, mole fraction of He contents. As a result of the qualification test, the weld quality of end closure welding of SFR metallic fuel rod was qualified and the welding process is ready to produce SFR metallic fuel rods under the qualified conditions.

## 5. Conclusions

Through the qualification test, the weld quality of end closure welding of SFR metallic fuel rod was evaluated according to the qualification test plan and satisfied the requirements on the weld. Consequently the qualified welding process is ready to produce SFR metallic fuel rods.

## ACKNOWLEDGEMENTS

This work has been carried out under the Nuclear Research and Development Program supported by the Ministry of Science, Ict and Future Planning in the Republic of Korea.

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