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End Closure Welding of SFR Metallic Fuel Rod by GTAW

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1. Introduction

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, TRU bearing metallic fuel, U-TRU-Zr alloy fuel, was selected and is being developed. And also the international collaborative research is under way on fuel developments with the closed fuel cycle of full actinide recycling, within Advanced Fuel Project for international generation IV (Gen-IV) SFR.

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.

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 welding technique, welding equipment, welding conditions and parameters were developed for the end closure of SFR metallic fuel rods. The gas tungsten arc welding (GTAW) technique was adopted and the welding joint design was developed. And the optimal welding conditions and parameters were established.

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 [5]. Each fuel rods 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.

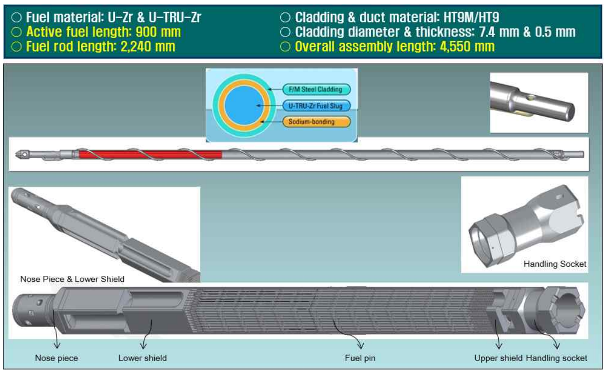

Fig. 1. SFR metallic fuel

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. In the case of GTAW, the equipment is simple and the welding procedures are not complicated, but the weld defects like undercut or pin-hole occur occasionally due to the features of fusion welding.

3.1 GTAW welding system

A GTAW welding system was developed for the end closure welding as shown in Fig. 2. It composed of a GTAW welder (Model Maxstar 200DX, Miller), a welding chamber, and an arc height controller (Model HAS-01-A-1, Hangil Industry co.).

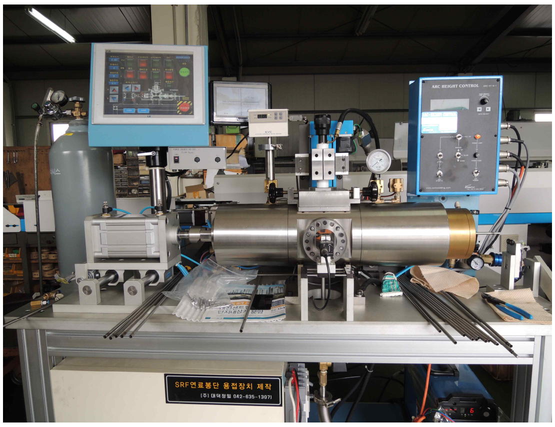

Fig. 2 Photograph of the GTAW welding system

3.2 Weld joint designs for end closures

There are many weld joint designs for fuel rod end closures [6,7]. Fig. 3 shows the original joint design for end closure of SFR fuel rod. This design showed some weld defects and poor weld quality in continuous welding for production as shown in Fig. 4.

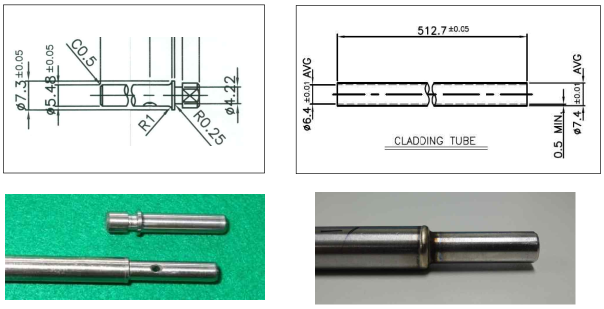

Fig. 3 Weld joint design for end closure

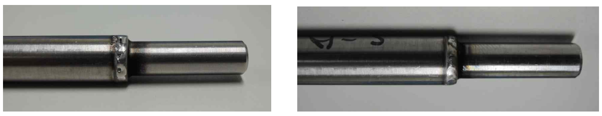

Fig. 4 Weld defects in the end closure

To improve the weld quality of end closure weld, 4 kinds of weld joint designs were developed and tested. Among them, the improved design as shown in Fig.5 was the optimal and selected for end closure of SFR fuel rod.

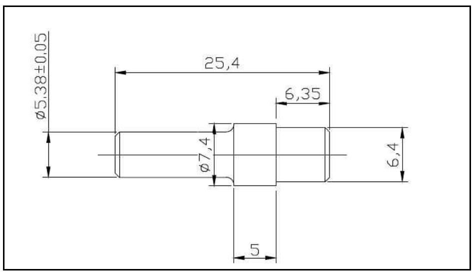

Fig. 5 Improved weld joint design

3.3 End plug welding by GTAW

For the optimal end plug welding conditions to make SFR metallic fuel rod, the performance tests were conducted as shown in Table 1.

Table 1: Experimental welding parameters

Gap		Rotation				Weld Current (A)
Volt (V)	stick-out (mm)	Total (°)	Speed (rpm)	Start (°)	End (°)	
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	34
8	0.7	2000	20	20	460	32
8	0.7	2000	20	20	460	34
8	0.7	2000	20	20	460	32
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	10	20	460	30
8	0.7	2000	15	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	20	20	460	30
8	0.7	2000	15	20	460	30
8	0.7	2000	15	20	460	30

The end plug and cladding tube material is HT9 stainless steel. As a result of the performance welding tests, a good weld shape and weld quality were obtained as shown in Fig. 6.

Fig. 6 Weld shape and Microstructure of end plug weld section

4. Conclusions

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.

ACKNOWLEDGEMENTS

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