Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Endplug Welding Techniques developed for SFR Metallic Fuel Elements

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1. Introduction

The international generation IV (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 SFR has been begun since 1997, as one of the national long-term nuclear R&D programs. The international collaborative research is under way on fuel developments within Advanced Fuel Project for Gen-IV SFR with the closed fuel cycle of full actinide recycling, while TRU bearing metallic fuel, U-TRU-Zr alloy fuel, was selected and is being developed.

For the fabrication of SFR metallic fuel elements, the endplug welding is a crucial process. The sealing of endplug to cladding tube should be hermetically perfect to prevent a leakage of fission gases and to maintain a good reactor performance [2]. In this study, the welding technique, welding equipment, welding conditions and parameters were developed to make SFR metallic fuel elements. The TIG welding technique was adopted and the welding joint design was developed. And the optimal welding conditions and parameters were also 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 the prototype reactor. As shown in this figure, a fuel assembly is composed of a nose piece and a handling socket in the end, and a duct in the middle part which contains 271 fuel elements assembled inside it [3]. Each fuel element has a lower endplug, a fuel slug, an upper gas plenum, and an upper endplug as shown in Fig. 2. The outside of fuel is wrapped with a wire. In inside of fuel element, the gap between fuel slug and fuel cladding is filled with sodium (Na). In principle, a closed fuel cycle is based on recycling a used fuel discharged from a 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 manner 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.

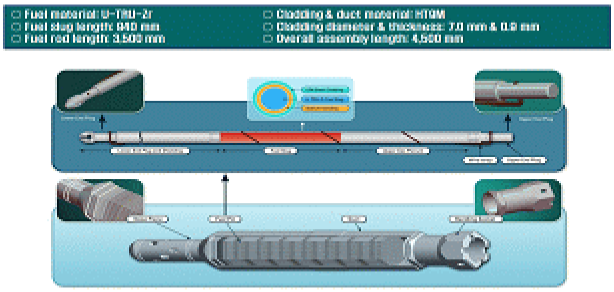

Fig. 1. SFR metallic fuel

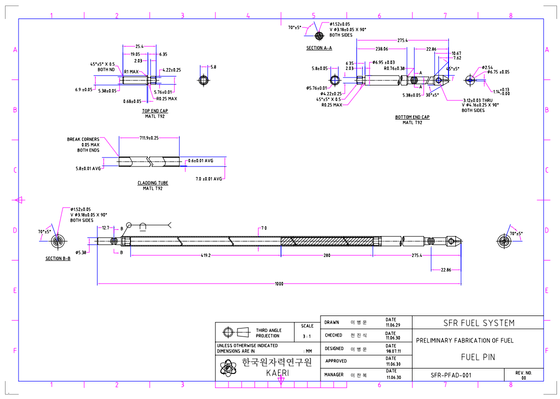

Fig. 2. Drawing of SFR metallic fuel element

3. Endplug Welding

There are many commercialized welding techniques such as tungsten inert gas welding (TIG), 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 endplug welding of PWR fuel elements and CANDU fuel rods in a commercial basis. The endplug welding should be selected and developed in consideration of weldability, weld joint design, production efficiency, etc. In the case of TIG, 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 Endplug welding system

A TIG welding system was developed for the endplug closure welding as shown in Fig. 3. It composed of a TIG welder (Model Maxstar 200DX, Miller), a welding chamber, and an arc height controller (Model HAS-01-A-1, Hangil Industry co.).

Fig. 3 Photograph of the TIG welding system

3.2 Endplug welding by TIG

For the optimal endplug welding conditions to make SFR metallic fuel elements, the performance tests were conducted. As shown in Fig. 4, the welding joint design was developed to plug an endplug into a cladding tube.

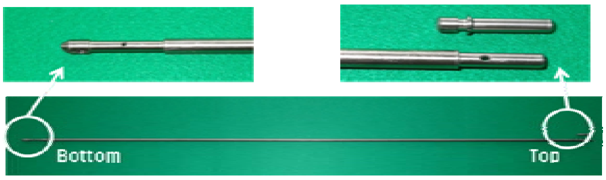

Fig. 4 Photograph of the TIG welding system

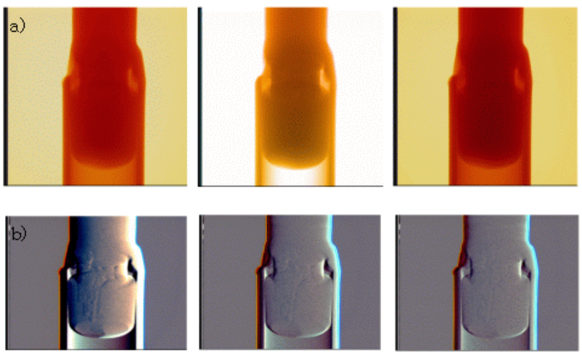

Fig. 5 Cross-section of endplug part welded by TIG

The endplug and cladding tube material is HT9 stainless steel. The welding parameters were as follows;

- Rotation speed : 10 rpm
- Welding starting angle : 50°
- Welding finishing angle : 460°
- Welding current : 15A, 27A
- Welding atmosphere : He 1 atm, Ar 2 kg/cm^2

As a result of the performance welding tests, a good weld shape and weldability was obtained as shown in Fig. 5 and Fig. 6.

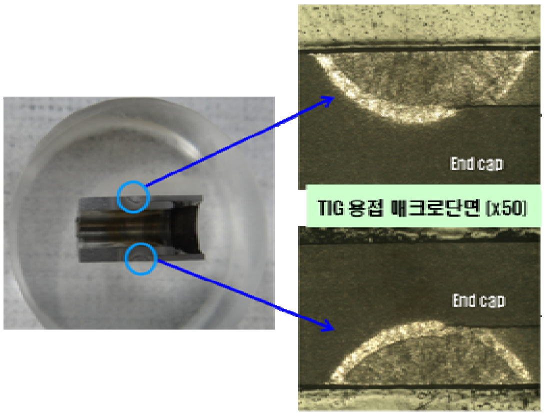

Fig. 6 Microstructure of endplug weld section

4. Conclusions

In order to make SFR metallic fuel elements, the welding technique, welding equipment, welding conditions and parameters were developed. The TIG welding technique was adopted and the welding joint design was developed. And the optimal welding conditions and parameters were also established.

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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