Weld Joint Design for SFR Metallic Fuel Element Closures

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1. Introduction

The Generation IV (Gen-IV) program, aiming to continue the sustainable development of nuclear power utilization was internationally started from 2000 [1]. The sodium-cooled fast reactor (SFR) system is among the six systems selected for Gen-IV promising systems and expected to become available for commercial introduction around 2030. 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 joint designs for endplug welding were investigated. For the irradiation test of SFR metallic fuel element, the TIG welding technique was adopted and the welding joint design was developed based on the welding conditions and parameters established.

2. Features of SFR metallic fuel

The specifications and dimensions of SFR metallic fuel assembly are shown in Fig.1, 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. 1. 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.

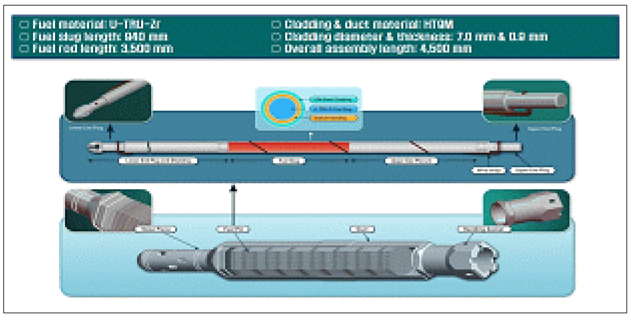


Fig. 1 SFR metallic fuel

3. TIG 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, the TIG welding technique was adopted to make SFR metallic fuel elements for the irradiation test, because 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 TIG welding system

A TIG welding system was developed for the endplug closure welding as shown in Fig. 2. 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.).

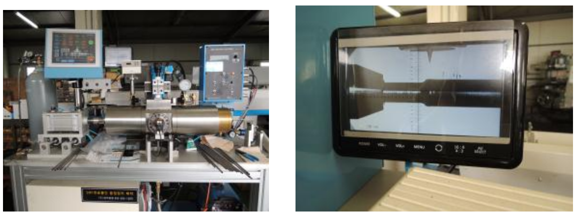
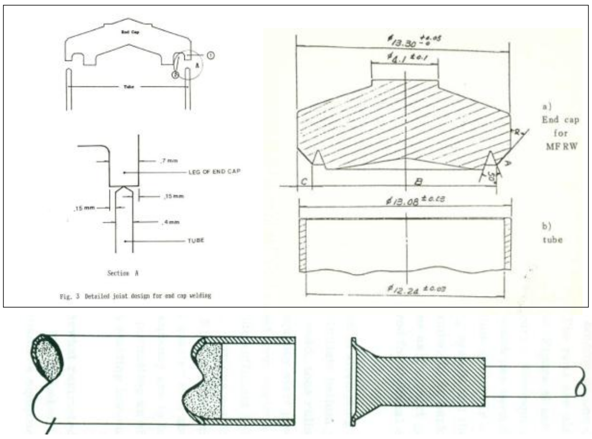


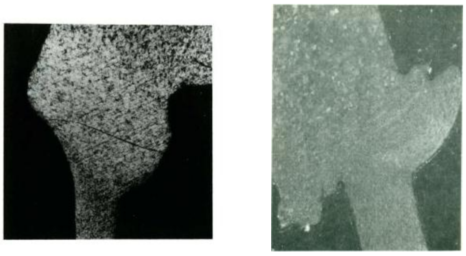
Fig. 2 Photograph of the TIG welding systm

3.2 Weld joint designs for end closures

There are many weld joint designs for fuel rod end closures as shown in Fig. 3,4 [4,5]. Fig. 3 shows the joint design for resistance upset butt welding. And Fig. 4 shows the joint design for tungsten inert gas welding (TIG), electron beam welding (EBW), and laser beam welding (LBW).

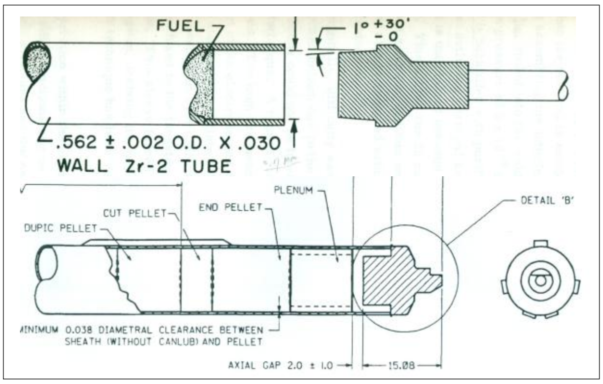


(a) Joint design

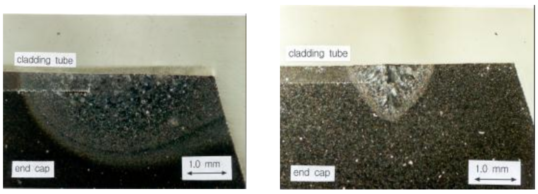


(b) Weld shape

Fig. 3 Weld joint designs for solid state welding (RW)



(a) Joint design



(b)Weld shape

Fig. 4 Weld joint designs for fusion welding (TIG, LBW)

For the optimal endplug welding to make SFR metallic fuel elements, the performance tests were conducted based on the TIG weld joint designs. As shown in Fig. 5,6, the weld joint design was developed to plug an endplug into a cladding tube.

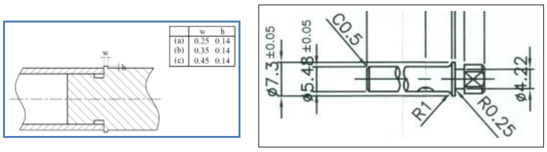


Fig. 5 Weld joint design for SFR fuel elements closures

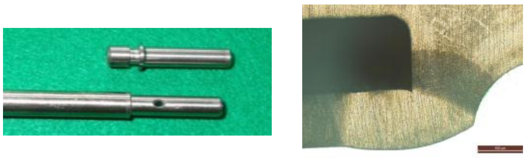
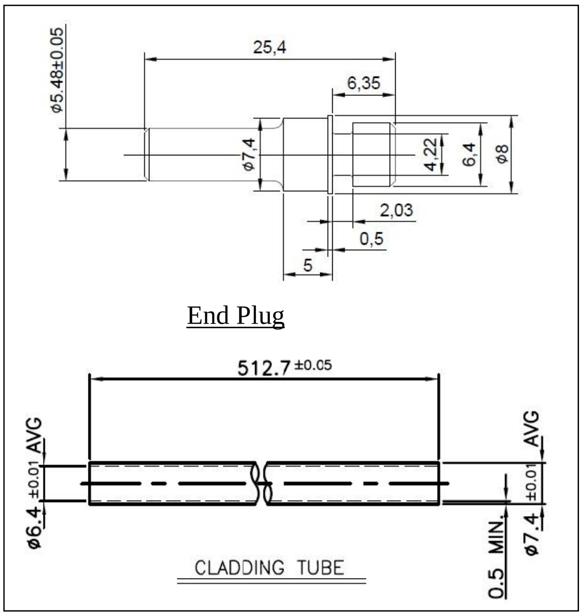


Fig. 6 Weld joint parts and shape for SFR fuel elements closures

3.3 Selected joint design for desired welding

Based on the results of welding experiments, the weld joint was selected for SFR metallic fuel element closures as shown in Fig. 7(a).



(a) End plug design for desired weld

(b) Weld shape

Fig. 7 Selected joint design and weld shape for SFR fuel elements closures

For a good heat balance and an easy adjustment of the gap between electrode and weld line, the shoulder of endplug was extended to 5 mm from 0.68 mm. It showed a good weld shape as shown in Fig. 7(b).

4. Conclusions

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

ACKNOWLEDGEMENTS

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