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Gas Tungsten Arc Welding for Fabrication of SFR Fuel Rodlet

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1. Introduction

In Korea, R&D on a sodium-cooled fast reactor (SFR) was begun in 1997, and a Prototype Generation-IV Sodium-cooled Fast Reactor (PGSFR) is being developed in collaboration with the Gen-IV program. As a fuel for PGSFR, metallic fuel, U-Zr alloy fuel, was selected and is being developed. And U-TRU-Zr fuel development is under way in combination with the pyro-electrochemical processing of spent PWR fuel [1]. To evaluate the PGSFR fuel performance, the irradiation test in HANARO research reactor was planned and the fuel rodlet to be used for irradiation test should be fabricated under the appropriate Quality Assurance (QA) program. For the fabrication of PGSFR metallic fuel rodlets, 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 end plug welding of fuel rodlet for irradiation test in HANARO was carried out based on the qualified welding technique as reported in the previous paper [5].

2. Requirements of fuel rodlet for irradiation test

Fig. 1 shows the dimensions of PGSFR metallic fuel rodlet for the irradiation test in HANARO research reactor. The fuel rodelts to be assembled for the irradiation capsule is shown in Table 1. As shown in Table 1, 3 kinds of cladding materials, HT9, FC92B, FC92N and 2 kinds of slug materials, U-10%Zr and U-10%Zr-4%RE and 2 kinds of tube size, O.D. 7.4 mm and O.D. 5.5 mm, are used for the irradiation test.

Table 1. Arrangements of fuel rodlets in capsule.

Location	ID No.	Fuel Slug	Cladding Material	Barrier Coating
Upper (O.D. 7.4 mm)	1	U-10%Zr	FC92B	
	2	U-10%Zr-4%RE*	FC92B	Cr
	3	U-10%Zr	FC92N	
	4	U-10%Zr-4%RE*	FC92N	Cr
	5	U-10%Zr	HT9	
	6	U-10%Zr-4%RE*	HT9	
Lower (O.D. 5.5 mm)	1	U-10%Zr	FC92B	
	2	U-10%Zr-4%RE*	FC92B	Cr
	3	U-10%Zr	FC92N	
	4	U-10%Zr-4%RE*	FC92N	Cr
	5	U-10%Zr	HT9	
	6	U-10%Zr-4%RE*	HT9	Cr

*RE ; Nd 53%, Ce 25%, Pr 16%, La 6%

The fuel assembly is composed of fuel rodlet and fuel sealing tube. Each fuel rodlet has a lower end plug, a fuel slug, an upper gas plenum, and an upper end plug as shown in Fig. 1. The inside of the fuel rodlet, the gap between the fuel slug and fuel cladding is filled with sodium (Na). The plenum is filled with 1 atmosphere of He gas. After end plug welding, the He leak rate should be less than $5x10^{-8}$ cm^3/s.

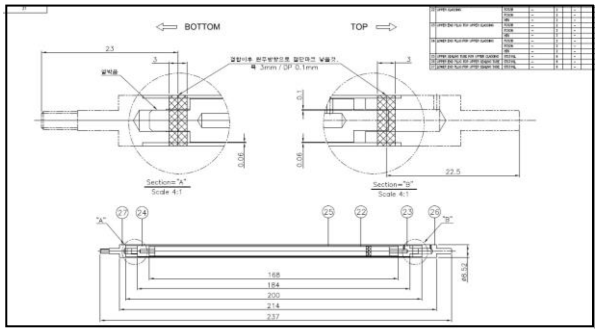

Fig. 1. Drawing of fuel rodlet for HANARO irradiation test.

3. GTAW for End Plug Welding

Gas Tungsten Arc Welding (GTAW) melts the weld joint by an electric arc generated between the tip of a tungsten electrode and the weld joint. A GTAW system for end plug welding was developed, as shown in Fig. 2.

Fig. 2. Photograph of the GTAW system for end plug welding.

End plug welding is carried out in a He gas atmosphere confined in a welding chamber. The welding chamber accommodates the weld joint and is evacuated to remove air gas, and is back filled with high purity (99.999%) He gas to fill the inner space of the fuel rod. A welding torch containing a welding electrode is located on top of the welding chamber. The weld joint is positioned directly under the welding electrode. The cladding tube plugged with an end plug is rotated and welding is conducted by the arc generated between the cladding tube and welding electrode. A CCTV camera was used to monitor the alignment of the weld joint and the arc during the welding process. In addition, an arc height controller (Model HAS-01-A-1, Hangil Industry co.) was introduced to adjust the gap between the cladding tube and the tip of the welding electrode.

3. End Plug Welding

For the end plug welding of fuel rodlets, GTAW was carried out according to the qualified welding technique as reported in the previous paper [5]. And also for the evaluation of the weld quality, the following inspections were conducted.

- Visual inspection
- X-ray radiography
- He- leak testing
- Dimension measuring
- Metallographic examination
- Tensile test
- Microhardness testing

The following quality criteria were applied to prove the weld integrity.

- The fabricated fuel rodlets shall meet all dimensions described in the drawing.
- The end plug to tube weld shall have tensile strength equal to or greater than those of the tube material.
- The weld joint between the end plug and tube shall consist of sound metal, the effective length of which, in the radial projection, shall be no less than 90% of the tube thickness.
- Fuel rodlets shall be helium leak tested. All fuel elements showing a detectable helium leak rate (>5×10^{-8} cm^3/s) shall be rejected.
- The weld area shall have micro-hardness value equal to or greater than 350 Hv.

The end plug welding was carried out at the weld current 30A for upper rodlets(O.D. 7.4 mm) and 25A for lower rodlets(O.D. 5.5 mm). The welding was successfully conducted. The inspections to evaluate the weld quality were conducted and the inspection results were obtained as shown in Fig. 3 to Fig. 6. The results showed the weld integrity well satisfied with the quality criteria.


Fig. 3. Visual inspection result

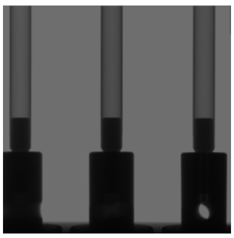
Fig. 4. X-ray radiography result

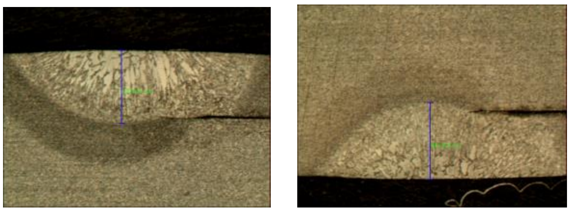
Fig. 5. Metallographic examination result


Fig. 6. Tensile test result.

As shown in Fig. 3 to Fig. 6, the results of visual inspection, X-ray radiography, metallographic examination, tensile test and micro-hardness test satisfied the quality criteria on the weld. And also it was not found any leakage in a helium leak test. As a result of the inspections, the weld quality of end plug welding of fuel rodlet for irradiation test in HANARO was proved to be in good weld integrity.

5. Conclusions

The end plug welding of fuel rodlets for irradiation test in HANARO was successfully carried out under the appropriate QA program. The results of the quality inspections on the end plug weld satisfied well the quality criteria on the weld. Consequently the fabricated fuel rodlets are ready for irradiation test in HANARO.

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