Development of the Pin-hole Welding Technology for a Fuel Irradiation Test

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1. Introduction

The irradiation test of fuel specimens was planned for the evaluation of a nuclear fuels performance.[1,2,3] To establish the welding technology process, satisfying the requirements of the irradiation test, an orbital-GTA weld machine for fuel specimens was developed, and the preliminary welding experiments for optimizing the process conditions of the fuel specimens were performed. Fuel specimens with a 9.5mm diameter and a 0.6mm wall thickness of the cladding tubes and end caps have been used and the optimum conditions of the pin-hole welding have been selected.

This paper describes the experimental results of the pin-hole welds of the fuel specimens and the metallography examinations of the pin-hole welded specimens for various pressure conditions for the fuel irradiation test using the 3-pin FTL. These investigations satisfied the requirements of the irradiation test and the pin-hole welds for the fuel specimens at the HANARO research reactor.

2. Materials and Results

2.1 Test Materials

For the fuel fabrication of the irradiation test, All the specimens were prepared with Zr-4 end caps and cladding tubes based on the drawing No. of the HAN-IC-DW-WD-TF-ASS'Y. For the pin-hole welding of the Zr-4 cladding tubes, the configuration of the specimens was also prepared as shown in Fig. 1.

2.2 Welding Machine

Welding machine was developed as shown in Fig. 2 by using a GTA weld head torch in order to do a spot welding of the fuel specimen. The welding system consists of a weld head torch, vacuum chamber and a specimen holder. The weld head torch is adjusted at the upper side of the cladding tube with a hole of about 1.0mm as shown in Fig. 1. The inert gas in the vacuum chamber was He of UPC grade, and the vacuum rate was $3x10^{-2}$ torr.

2.3 Examination Procedure

The macro-sections of the welded specimens were investigated by a metallograph to determine the penetration depth of the Zr-4 cladding tube. The welded specimens using zircaloy-4 cladding tube were polished and etched with the following etchant : H_2O 45%, HNO_3 45%, HF 10% (Vol.%).

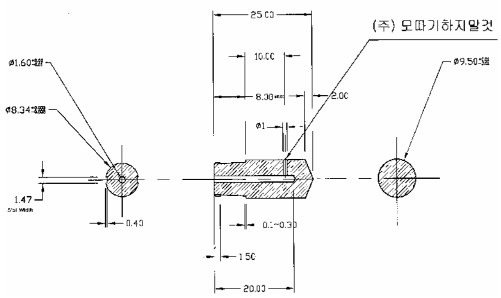

Fig 1. Configuration of the pin-hole specimen.

Fig 2. Photography of the GTA welding system.

2.4 Optimization of the pin-hole welding

When the internal pressure of the fuel specimen for the fuel irradiation test was required, the fuel specimen was basically pressurized by using the He gas. On the integrity of the fuel specimen after the plug welding between the end plug and the Zr-4 cladding tube, it was necessary to finish it with a pin-hole welding and to avoid the burst-phenomenon in the welding area due to the gas expansion during the final welding.[4] In the pin-hole welding experiments, some parameters were important to determine the effective penetration depth of the welding area. The Zr-4 cladding tube sampled from the position of the pin-hole as shown in Fig. 1 was used to determine the suitable welding current and the holding time. In this experimental result as shown in Table 1, the optimal data for the pin-hole welding was proposed for the fuel specimen for the fuel irradiation test.

Table 1. Welding parameters used for the pin-hole specimens.

Conditions	Parameter 1	Parameter 2	
Current/Time	80A 0.3 sec.	80A 0.4 sec.	(Fixed by weld head torch)

2.5 Investigation of the Welding Characteristics Using High Pressure Conditions

In these welding experiments with a high pressure condition, pin-hole welded specimens were performed by a visual test, He leak inspection and metallography examinations to check the penetration depth and the weld defects. Fig. 3 shows comparatively the macro-sections of the pin-hole welded specimens. All the specimens show that the penetration depth is very similar to the thickness of the Zr-4 cladding tube, and weld defects of the fuel specimens were not found. Fig. 4 shows the relations between the bead width and the penetration depth, with increasing pressure conditions, the penetration depth increased remarkably. Especially it also shows that the bead width was slightly wider than that of the specimens with lower pressure conditions. This was probably due to the higher fusion rates when compared with that of the lower pressure conditions during the solidification of the weld metal. In this experimental result, the soundness of the pin-hole welds quality for the fuel specimens has been confirmed by the macro-section of the welds and the microstructure examinations.

3. Conclusion

Satisfactory GTA welding technology for pin-hole test specimens was developed. The pin-hole welded specimens were free of defects and had good penetration depths of the Zr-4 cladding tubes. The GTA welds performed under high pressure conditions were as good as the GTA welds made in an inert gas chamber. Based on this development experience, the pin-hole welding technique will provide a useful data for the fuel specimen fabrication using a 3-pin FTL at the HANARO research reactor.

5bar	10bar	15bar	20bar	25bar

Fig. 3. Macro-sections of the pin-hole welded specimens.

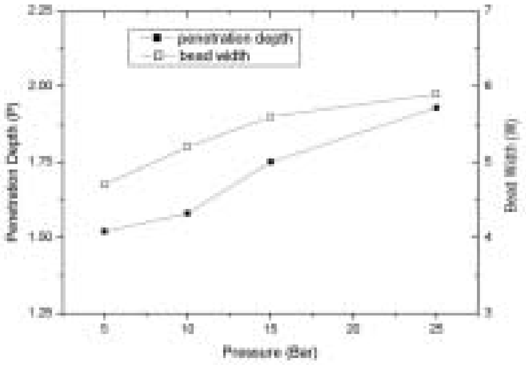

Fig. 4. Relations between the bead widths and the penetration depth on various pressure conditions.

Acknowledgements

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