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Development of a Dual Rod Fabrication for an Instrumented Fuel Irradiation Test

Soo-Sung Kim, Woon-Taeg Shin, Jae-Min Sohn and Bong-Goo Kim
Capsule Development & Utilization Dept., Korea Atomic Energy Research Institute, Daejeon, sskim7@kaeri.re.kr

1. Introduction

The irradiation test of dual rod specimens was planned for the evaluation of a nuclear fuels performance.[1,2,3] To establish the fabrication process, and for satisfying the requirements of the irradiation test, an orbital-GTA weld machine for the specimens of the dual rods was developed, and the preliminary welding experiments for optimizing the process conditions of the specimens of the dual rods were performed. Dual rods 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 also been selected.

This paper describes the experimental results of the GTA welds of the specimens of the dual rods and the metallography examinations of the GTA welded specimens for various welding conditions for the instrumented fuel irradiation test. These investigations satisfied the requirements of the instrumented irradiation test and the GTA welds for the specimens of the dual rods at the HANARO research reactor.

2. Materials and Results

2.1 Test Materials

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

2.2 Welding Chamber

Welding chamber was developed as shown in Fig. 2 by using a GTA head torch in order to achieve a circumferential welding. The GTAW machine consists of a weld head torch, vacuum chamber and specimen holder. The torch head of the GTA welder used the orbital tube method. 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 dual rod specimens were investigated by a metallograph to determine the penetration depth of the Zr-4 cladding tube. The welded specimens using the plugs and cladding tubes were polished and etched with the following etchant : H_2O 45%, HNO_3 45%, HF 10% (Vol.%).

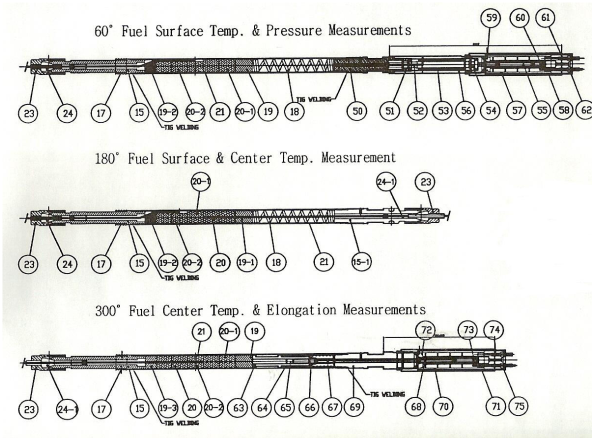


Fig 1. Configuration of the dual rod specimens.

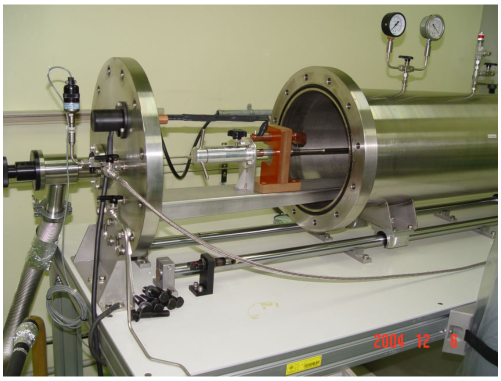


Fig 2. Photography of the GTA welding chamber.

2.4 Investigation of the dual rod welding

The autogenous melting method has a significant effect on the dual rod welding. If the solidification of the weld pool is brought about only in one direction while welding, it can be easily melted. Usually, a GTA welding causes a molten pool in the material more easily than the other welding methods, and a deep penetration can be made by the GTA welding. Fig. 3 shows the typical sectional views of the upper and lower sides during the dual rod welding. As shown in Fig. 3, the lower side of the weld zone was found to have a much larger penetration, when compared with the upper side of the weld zone. Moreover, GTA welded zone usually had a larger melting volume compared with the other welding methods, which melt by a high input energy. The dual rods sampled from the position of the pin-hole were welded by the current and the holding time as shown in Table 1. In this experimental result of the pin-hole specimens as shown in Fig. 4, the welding data for the pin-hole sealing was proposed for the instrumented fuel irradiation test.

Table 1. Weld parameters used for the dual rod specimens.

Conditions	Parameter 1	Parameter 2	1 : Dual rod WD 2 : Pin-hole WD
Current/Time	25-24-24-23 A 5-6-6-5 sec.	80A 0.3 sec.	2 : Fixed by weld head torch

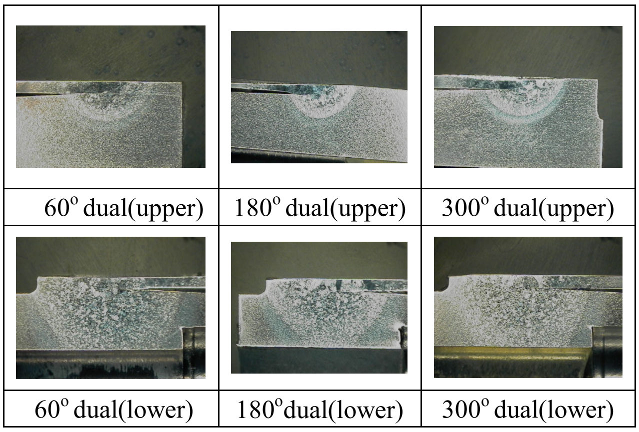


Fig. 3. Macro-sections of the upper and lower sides with dual rod specimens.

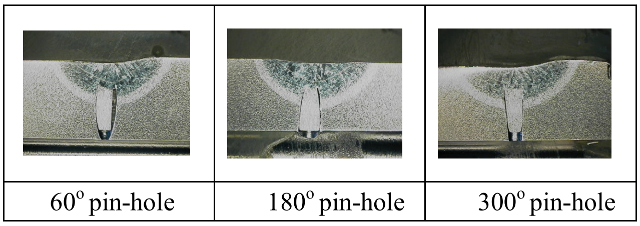
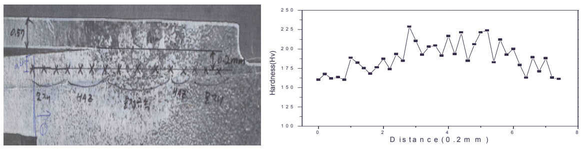


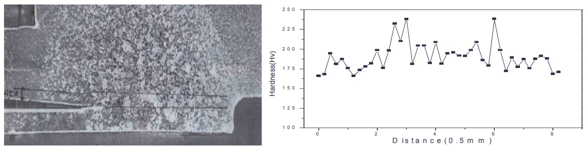
Fig. 4. Macro-sections of the pin-hole welded specimens.

2.5 Evaluation of the micro-hardness test using the GTA welded specimens

The hardness test was conducted at the base metal, HAZ and the weld metal by the Vickers hardness tester. Fig. 4 shows comparatively the results of the specimen welded at the upper side and lower side. In the lower side of the welded specimen, the micro-hardness of the weld metal was found to be in the range of 180 Hv to 230 Hv, and the hardness of HAZ between the weld metal and the base metal was found to be in the range of 150 Hv to 180 Hv. The difference of the hardness of the weld metal between the upper and low side welded specimen was so narrow, but for the hardness of the weld metal, the upper side was found to be smaller than that of the lower side by about 10 Hv to 20 Hv. Also, the weld metal and HAZ area of the upper side of the GTA welded specimen was found to be narrower, when compared with the lower side of the GTA welded specimen.



(upper side)



(lower side)

Fig. 4. Micro-hardness variations along cladding tube-HAZ-end plug of the GTA welded specimen.

3. Conclusion

Satisfactory GTA welding technology of the dual rod for the instrumented fuel irradiation test was developed. The dual rods of the GTA welded specimens were free of defects and had good penetration depths of the Zr-4 cladding tubes on the dual types respectively. Based on this welding experience, a fuel rod fabrication will be provided for the instrumented fuel irradiation test at the HANARO research reactor.

Acknowledgements

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