Development of GTA Welding Technology for Dual Cooled Fuel Rods

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1. Introduction

The irradiation test of dual cooled fuel rod specimens was planned for the evaluation of a nuclear fuel performance.[1,2] To establish the fabrication process, and for satisfying the requirements of the irradiation test, an GTA(Gas Tungsten Arc) welding machine for the dual cooled rods specimens was developed, and the preliminary welding experiments were performed to optimize the welding process conditions. Cladding tubes of 15.9 and 9 mm for the outer and inner diameters, respectively with a 0.57 mm thickness and end caps were used for the specimens.

This paper describes the experimental results of the GTA welds and the micrograph examinations of the GTA welded specimens corresponding to various welding conditions for the dual cooled fuel irradiation test. The investigations revealed that the present GTA process satisfied the requirements for the fuel irradiation test in the HANARO research reactor.

2. Materials and Experimental Results

2.1 Specimen Materials

All the specimens of the end caps and cladding tubes were made of SUS 316. Fig. 1 shows the components of a fuel rod specimen for the welding tests.

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, a vacuum chamber and a specimen holder. The torch head of the GTA welder used the linear guider method. The inert gas in the vacuum chamber was He of a 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 micrograph to determine the penetration depth of the SUS 316 cladding tube. The welded specimens using the caps and cladding tubes were polished and etched electrically with the following etchant : H_2O 90%, oxalic acid 10% (Vol.%).

Fig 1. View of the fuel rod welding specimen components.

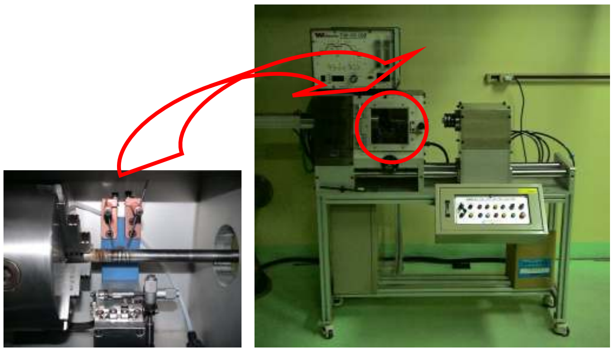

Fig 2. Photography of the GTA welding chamber.

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 a material more easily than the other welding methods, and a deep penetration can be made by a 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, the GTA welded zone usually had a larger melting volume compared with the other welding methods, which was melt by a high input energy. The dual rods sampled from the position of the inner tube were welded by the base current and the configuration size as shown in Table 1. In this experimental result of the inner tube specimens as shown in Fig. 4, the welding data for the inner tube sealing was proposed for the instrumented fuel irradiation test. As a result of examining the characteristics of the penetration depth of the end cap welding by the GTA, it was found that the optimum weld parameters for the circumferential welding would be at least 40 A of a base current and 5 A of the back ground current to be welded.

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

Conditions	Parameter 1	Parameter 2	1 : Dual rod WD 2 : Inner tube WD
Current (main/sub A)	31-40-40(A) 05-05-10(A)	29 -12 – 25 (A) 2/1- 2/0.5-1/0.5	2 : Inclined by head torch

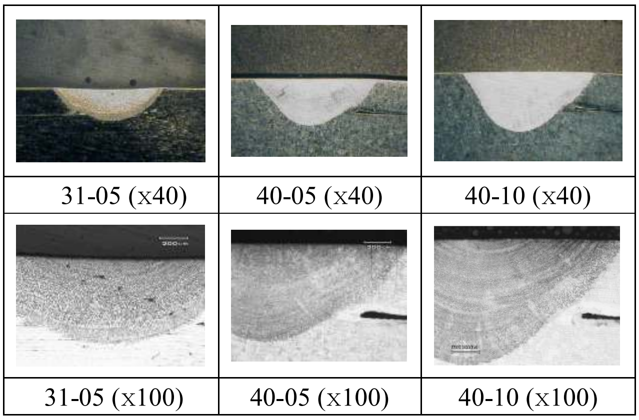

Fig. 3. Macro-sections and microstructures of SUS 316 weld metals with dual rod specimens.

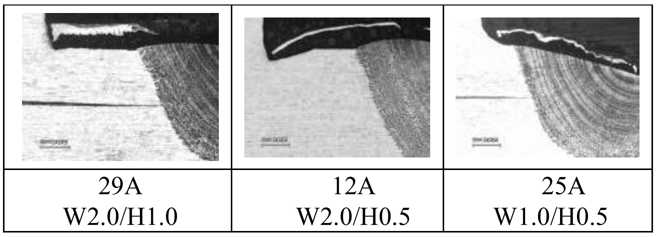

Fig. 4. Microstructures of the SUS 316 welded specimens with inner tubes and end caps.

2.5 Microstructure observation of the SUS 316 welded specimens

Fig. 5 provides an optical microscopic view of microstructural variation of the typical SUS 316 welds. The observation in which the weld metal solidifies is also considered. The fact that a melting occurs implies that the base metal is locally welded to its melting point, and this has certain repercussions concerning the microstructure of the base metal. The very importance of these is that a grain growth is likely to occur in the base metal, and this will be the greatest at the highest temperatures, i.e. nearest the fusion line between the melted and unmelted metal. The reason that a grain growth is important in this respect is that it is well established that, in fusion welding, an initial solidification occurs epitaxially. That is it so can be easily seen from the micrograph in Fig. 5, which shows that the crystals of the weld metal have been derived from the grains of the base metal.

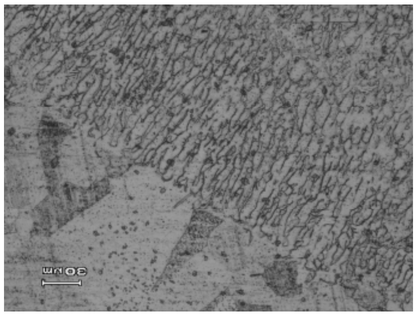

Fig. 5. Microstructure of the SUS 316 weld metal with the GTA welded specimen.

3. Conclusion

Satisfactory GTA welding technology for a dual cooled fuel rod for a fuel irradiation test was developed. The dual rods of the GTA welded specimens were free of defects and had good penetration depths. Based on this welding experience, a fuel rod specimen will be provided for a fuel irradiation test at the HANARO research reactor.

Acknowledgements

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