Evaluation of Electron Beam Welding Performance of AA6061-T6 Plate-type Fuel Assembly

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1. Introduction

As one of the most commonly used heat-treatable aluminum alloys, AA6061-T6 aluminum alloy is available in a wide range of structural materials. Typically, it is used in structural members, auto-body sheet and many other applications.[1] Generally, this alloy is easily welded by conventional GTAW (Gas Tungsten Arc Welding), LBW (Laser Beam Welding) and EBW(Electron Beam Welding).[2] However, certain characteristics, such as solidification cracking, porosity, HAZ (Heat-affected Zone) degradation must be considered during welding. Because of high energy density and low heat input, especially LBW and EBW processes possess the advantage of minimizing the fusing zone and HAZ and producing deeper penetration than arc welding processes.

In present study, to apply for the plate-type nuclear fuel fabrication and assembly, a fundamental electron beam welding experiment using AA6061-T6 aluminum alloy specimens was conducted. Furthermore, to establish the suitable welding process, and satisfy the requirements of the weld quality, EBW apparatus using an electron welding gun and vacuum chamber was developed, and preliminary investigations for optimizing the welding parameters of the specimens using AA6061-T6 aluminum plates were also performed. The EB weld quality of AA6061-T6 aluminum alloy for the plate-type fuel assembly has been also studied by the weld penetrations of side plate to end fitting and fixing bar and weld inspections using computed tomography.

2. Materials and Results

2.1 Test Materials and Welding Operation

All materials used in this experiment are of commercial quality, AA6061-T6 aluminum alloy with 4.5mm thickness of side plate part. The welding operation was done at traveling speeds of 1200 mm/min. of side plate to end fitting and 900 mm/min. of fixing bar part without preheating. The beam current and accelerating voltage were maintained at 60 kV and 35 mA in a vacuum condition of 10^{-3} Torr.

2.2 Examination Procedure

Test specimens using a dummy assembly as shown in Fig. 1 were welded by EBW. The welding variables were changed in order to find the optimum set of conditions. Before welding, the test specimens were ultra-sonically cleaned in ethyl alcohol. The macro-structure of welded specimens was investigated by the optical microscopic examination. All welded specimens were etched with Keller's reagent to reveal welded sections and microstructures.

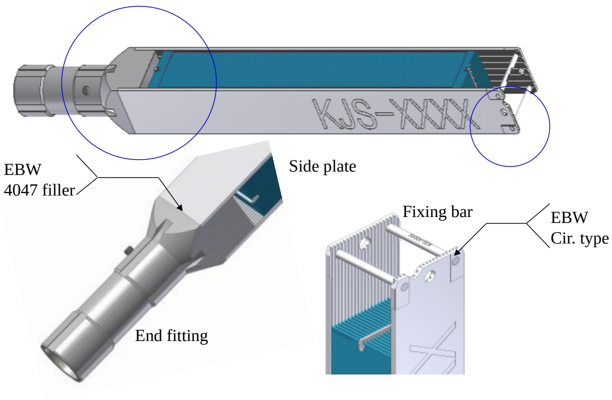

Fig. 1. Schematics of weld configuration using the plate-type fuel assembly.

2.4 Investigation of EB welds using fuel assembly

The fusion melting method using filler materials has a significant effect on the AA6061-T6 aluminum alloy welding. If the solidification of the weld pool is brought about only in one direction while welding, it can be easily melted. Usually, EB welding causes a molten pool in the material more easily than the other welding processes, and a deep penetration can be made by the EB welding. Fig. 2 shows the typical sectional views of the upper and lower sides during the side plate to end fitting welding. As shown in Fig. 2, 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, EB welded zone usually had a narrow melting volume compared with the other welding methods, which melt by a low heat input and high density energy. The circular joints sampled from the side plate to fixing bars were welded by the rotation axis controller as shown in Fig. 3. In these experimental results of the circular welded specimens, the welding data for the fixing bar parts was proposed for the plate-type fuel assembly.

2.5 Weld inspection by computed tomography

To find the weld defects and to confirm the soundness of the weld joints, a computed tomographic examination was conducted. The main purpose of the examination was to find out whether some defects such as lack of fusion and pores inside a weld metal can be detected by CT (Computed Tomography).[3] The results of computed tomographic examinations are given in Fig. 4 and 5, which show a 3D image and three projections of a sample specimen without a clearly evident lack of fusion and pores. In order to obtain a sound weld between a side plate part and end fitting part based on the experimental results, metallographic and a computed tomographic examinations of the welds, it can be suggested that accelerating voltage of 60 kV, a beam current of 35 mA, and weld speed of F1200 (1200mm/min.) with AA6061-T6 aluminum alloy are the optimized welding parameters for the configuration design in Fig. 1. These properties are satisfied with the requirements of the plate-type fuel assembly fabrication for the installation and commercialization at the research reactor.

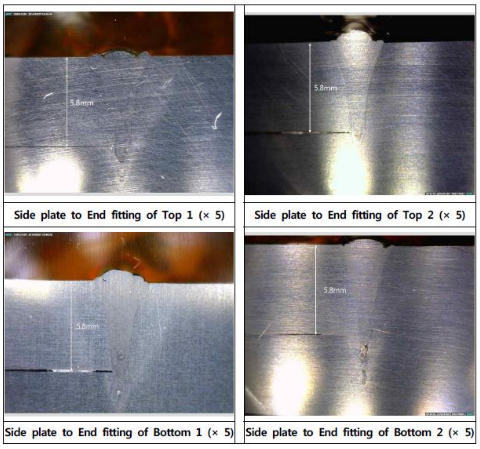

Fig. 2. Macro-sections of the upper and lower welds with side plate to end fitting parts.

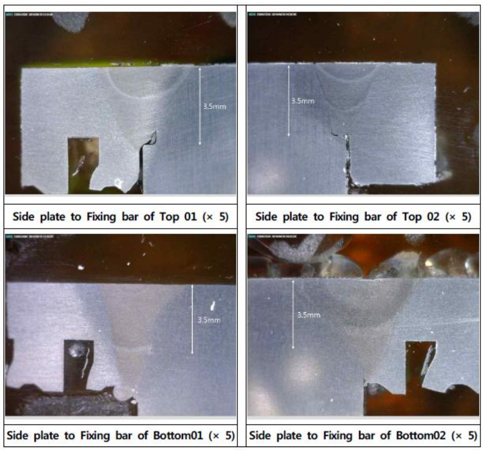

Fig. 3. Macro-sections of the upper and lower welds with side plate to fixing bar parts.

3. Conclusions

This study was carried out to determine the suitable welding parameters and to evaluate weld depths and sound welds of AA6061-T6 aluminum alloy. In the present experiment, satisfactory electron beam welding process of the full-sized sample was being developed. Based on this fundamental study, fabrication of the plate-type fuel assembly will be provided for the future Ki-Jang research reactor project.

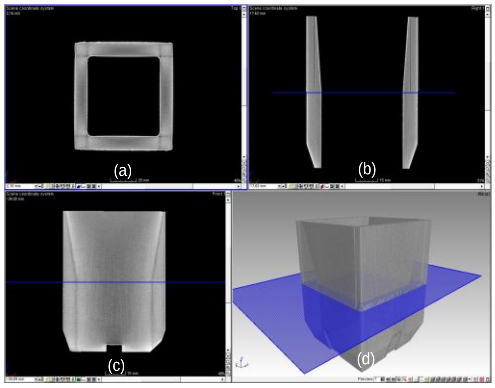

Fig. 4. Sample images of side plate to end fitting made by CT: (a) front, (b) side, (c) top view and (d) 3D image.

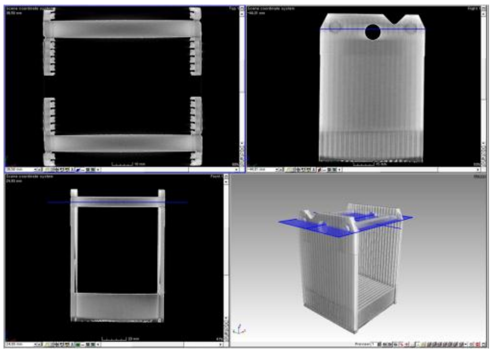

Fig. 5. Sample images of side plate to fixing bar made by CT: (a) front, (b) side, (c) top view and (d) 3D image.

Acknowledgements

This research was supported by the Development of key technologies for Research Reactor Fuel Development sponsored by the Ministry of Education, Science and Technology, and by a grant from the Fundamental R&D program from Core Technology of Materials Funded by the Ministry of Knowledge Economy, Republic of Korea.

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