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E-beam welding characteristic of the ARAA steel for the KO HCCR TBM

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1. Introduction

To develop the next generation technologies, the one of the important objects of ITER project is to investigate the heat extraction from the blanket module in a fusion reactor and tritium extraction experiments [1–7]. Korea has decided to test a helium cooled ceramic reflector (HCCR) test blanket module (TBM) in the ITER [8]. The HCCR TBM is composed of four sub-modules and a back manipulator (BM). And each sub-module is composed of a first wall (FW), a breeding box with s even-layer breeding zone (BZ), and side walls (SW) with the cooling path. In addition, Korea is being developed and evaluated advanced reduced activation alloy (ARAA) material as the HCCR TBM structure.

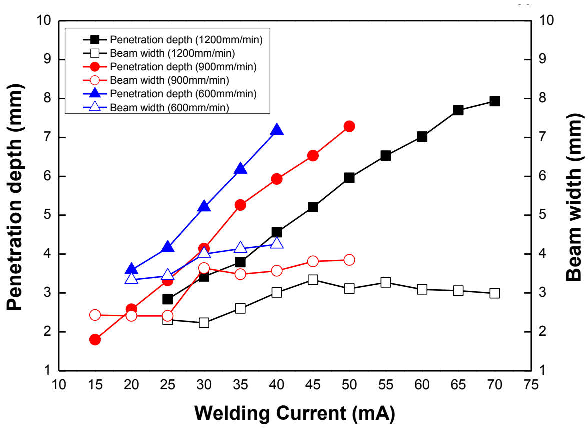
In this study, two thickness of ARAA plates, 8 and 13 mm, were carried out by electron beam (E-beam) weld to optimize the welding procedure considering weld speed and current, and investigated the variations in the weld bead width, an amount of dross, and the weld depth in both ARAA plates to optimize the fabrication procedure. Moreover, post weld heat treatment (PWHT) conditions were also carried out considering a different temperature and a cooling time. The micro-hardness measurements and Charpy Impact test in Base, heat affected zone (HAZ), and weld metal (WM) were carried out on E-beam welded joints after PWHT. The microstructural observation in the E-beam weld joints was also analyzed before and after PWHT condition.

The purpose of this study is to find the optimized E-beam weld condition, and analyze the mechanical properties and the influence of microstructure by E-beam weld of ARAA materials.

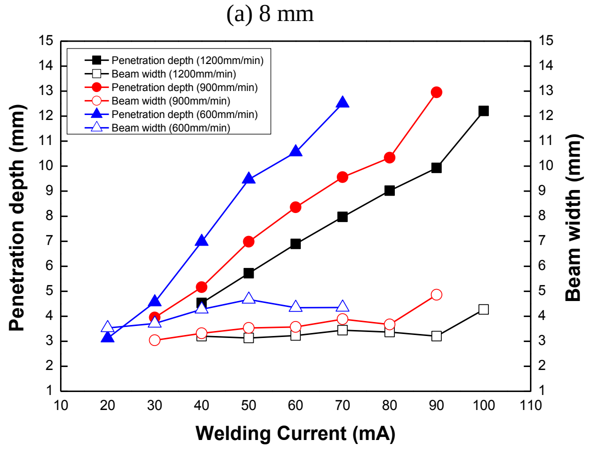
2. E-beam welding characteristic

2.1 E-beam welding characteristic

To find the optimized E-beam welding condition, two kinds of ARAA plates with the thickness of 8 and 13 mm were prepared. The considered the welding speed is 600, 900, and 1200 mm/min in both ARAA plates, and the penetration depth and beam width were investigated according to the E-beam welding current. Figure 1 shows penetration depth and beam width according to E-beam welding current in 8 and 13mm ARAA plates. Figure 1(a) and 1(b) show penetration depth and beam width according to E-beam welding current in 8 mm and 13 mm ARAA plates, respectively. It gives the similar tendency as the 8mm, as the current speed is increased, the penetration is depth is also increased according to the welding current; when the penetration depth is 13 mm, the weld current is 70 mA in weld speed of 600 mm/min, 90 mA in weld speed of 900 mm/min, and 100 mA in weld speed of 1200 mm/min. And the beam width is decreased as the welding current is increased as the same as Fig. 1 (a). Figure 2 shows the photograph of E-beam welding speed condition according to the welding current in ARAA plates, which are the results of Fig. 1. Figure 2 (a) and (b) show the amount of dross according to the welding speed and current in 8 mm and 13 mm ARAA plates, respectively.

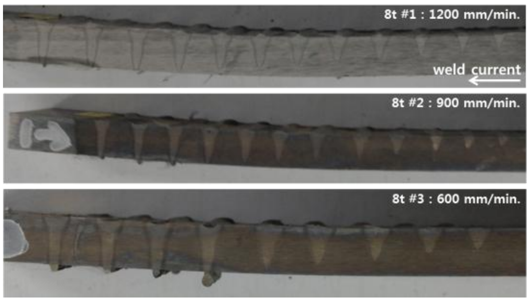


(a) 8 mm

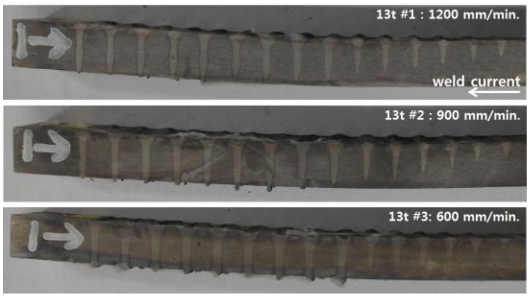


(b) 13 mm

Fig. 1. Penetration depth and beam width according to E-beam welding current in 8 and 13mm of ARAA plates.



(a) 8 mm of thickness



(b) 13 mm of thickness

Fig. 2. EB welding speed condition in ARAA plates

Fig. 3 shows the microstructure of 100 scales in the optimized E-beam weld of 13 mm ARAA plate.

2.2 Micro-hardness and Charpy Impact test

After carrying out of the optimized E-beam weld condition, PWHT condition was also investigate in ARAA plate of 13mm thickness.

Figure 4 show the Hardness result from the base metal (BM), through a heat affected zone (HAZ), to a weld metal (WM). The PWHT condition is also showed in the figure, and the hardness value is higher than other cases which are considered PWHT. Based on the results 730 °C PWHT condition is lower than other PWHT condition.

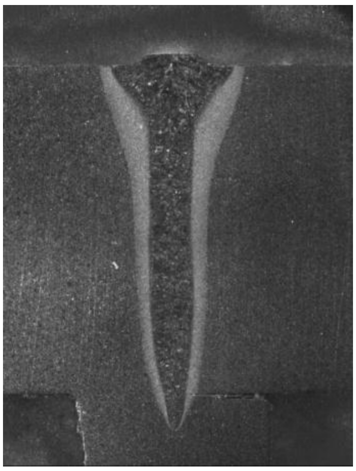


Fig. 3 Microstructure of the optimized E-beam weld condition in 13mm of ARAA plate

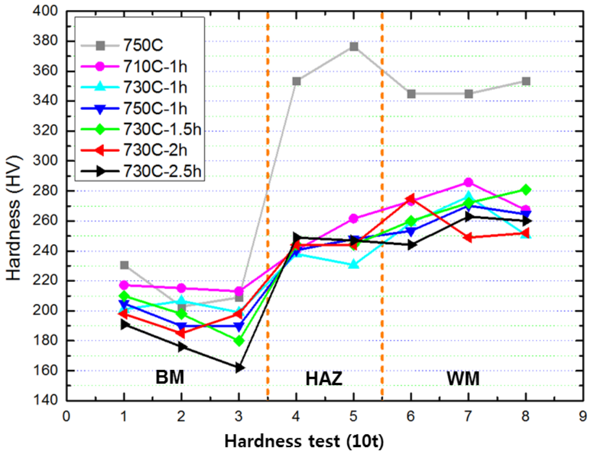


Fig. 4 Results of Hardness test from PWHT condition in ARAA plate

2.3 Microstructure Observation

The microstructure of the base and weld metal before and after PWHT condition were investigated as shown in Fig. 5. In the base metal region before PWHT, a fine precipitates with a tempered martensitic microstructure and ferrite structure are showed in the figure, but the base metal after PWHT shows the carbide shows clearer and become coarser than before PWHT condition. In the weld metal region before PWHT, the inhomogeneous solidification structure with elongated and bigger grain size show in the microstructure. But the weld metal region after PWHT shows that fine precipitated tempered martensitic microstructure and ferrite homogeneous solidification structure was observed, and the grain sizes smaller than the before PWHT condition.

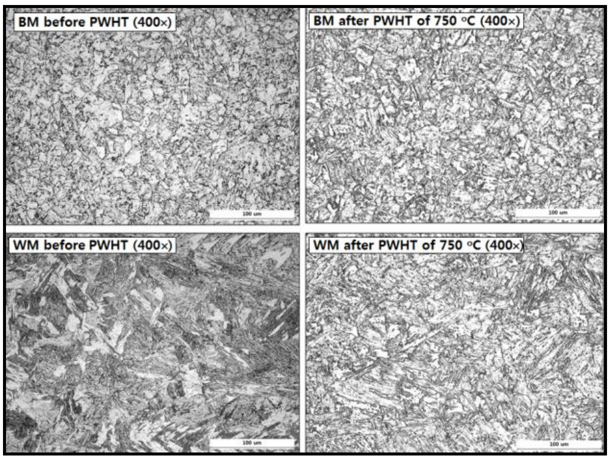


Fig. 5 Microstructure before and after PWHT condition in base and weld metal region.

3. Conclusions

To optimize the E-beam welding procedure from ARAA material, two kinds of ARAA plates, 8 and 13 mm, were prepared and carried out E-beam weld considering the weld speed and the current, and investigated the variations in the weld bead width, an amount of dross, and the weld depth. Based on the results 1200 mm/min of welding speed and 65 mA current in 8 mm thickness and 110 mA weld current in 13 mm thickness in ARAA plates gave the optimized weld condition. The PWHT condition was carried out and a micro-hardness and Charpy Impact test in BM, HAZ, and WM were conducted from the optimized E-beam welded joints. The microstructural observation in the E-beam weld joints was also analyzed. The PWHT results gave that 730 ^{o}C/1h of PWHT condition was a suitable PWHT condition from the micro-hardness and Charpy Impact test and microstructure observation.

Acknowledgments

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