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Development of Fabrication Procedure and Welding Performance Test for ITER HCCR TBM

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1. Introduction

Korea has developed and plans to test a Helium Cooled Ceramic Reflector (HCCR) Test Blanket Module (TBM) in the ITER [1]. The HCCR TBM is composed of four sub-modules and a back manipulator (BM). Each sub-module is composed of a first wall (FW), a breeding box with a seven-layer breeding zone (BZ), and side walls (SW) with a cooling path. The front surface of the sub-module is 231 mm in width and 835 mm in height. In the FW of the sub-module, there is a rectangular shape with 11 cooling channels 15 mm in width and 11 mm in height. The conceptual design and basic dimensions of the KO TBM are shown in Fig. 1. The fabrication procedure was developed to confirm the fabrication method for the HCCR TBM. The test specimens of the ARAA were prepared to test the weldability for tungsten inert gas (TIG) welding and electron beam (EB) welding. To establish and optimize the welding procedure in an EB weld from ARRA material, the variation in the bead width and penetration depth according to the welding current and welding speed were investigated. To verify the weldability and fabrication procedure for a complex structure such as the breeding zone, a small box with a cooling channel is being fabricated using the ARAA steel under development.

2. Design and fabrication procedure of the HCCR TBM sub-module

The fabrication procedure of the sub-module is machining each part of the FW, BZ, and SW, and then assembling the fabricated parts through welding and HIPping. The fabrication process of the FW was chosen and a half-scale sub-module FW was fabricated using this procedure [2]. The main fabrication sequence of the BZ and SW is machining each part and then welding the parts using TIG and E-beam welding. The HCCR TBM has four sub-modules, and each sub-module has a box shape with a rectangular structure with a faceted first wall (FW). The front surface of the sub-module is 231 mm in width and 835 mm in height. A HCCR TBM FW consists of three components: a front plate with a rectangular shape with 11 cooling channels 15 mm in width and 11 mm in height, a set of front covers, and a back plate. Diagrams of the three components of the mock-up and the manufacturing process are shown in Fig. 2. The fabrication method of the first wall was developed, and a half-scale sub-module mock-up using a SS316L was fabricated through this fabrication procedure [2]. A breeding zone has seven layers for the tritium breeding ratio, multiplier pebbles, a reflector, and cooling channels between each layer. The fabrication sequence of the breeding box is machining each part and then welding the parts using E-beam welding. The manufacturing process of the breeding box is shown in Fig. 3. After fabricating the first wall and breeding box, the sub-module of the HCCR TBM is finally manufactured by assembling the two parts using E-beam welding. A schematic diagram of the fabrication procedure of the sub-module is shown in Fig. 4.

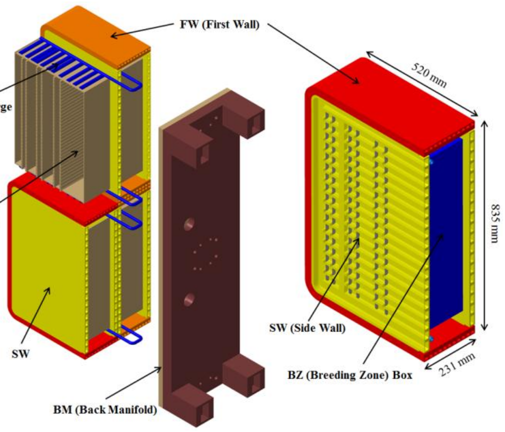

Fig. 1 Concept of KO HCCR TBM and its sub-module dimensions.

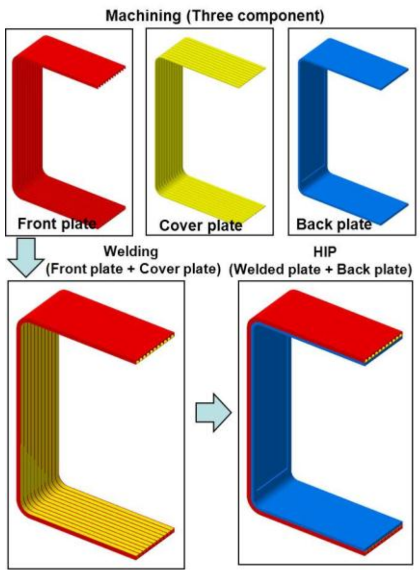

Fig. 2. Schematic diagrams of the manufacturing process of the HCCR TBM first wall.

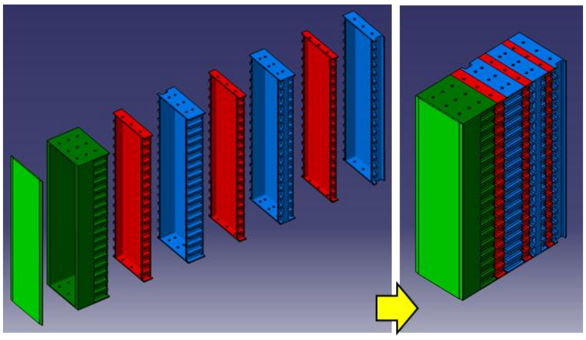

Fig. 3. Schematic diagrams of the manufacturing process of the HCCR TBM breeding zone.

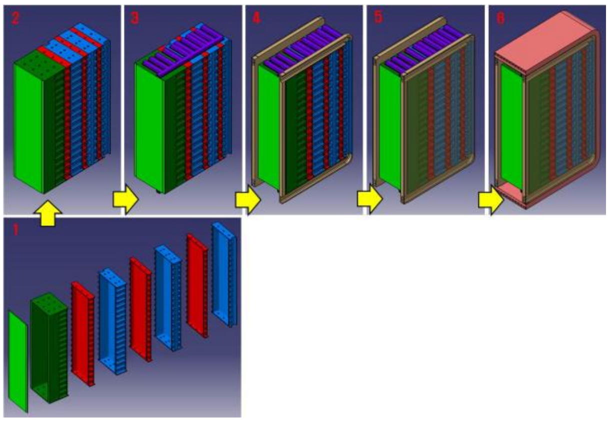

Fig. 4. Schematic diagrams of the manufacturing process of the HCCR TBM sub-module.

3. Welding performance test and developing manufacturing process for HCCR TBM

To establish and optimize the welding procedure for an E-beam weld from ARRA material, the variations in the bead width and penetration depth according to the welding current and welding speed were investigated using 8 mm thick ARRA material. The welding currents in the E-beam weld were first considered to be 25, 45, 65, and 85 mA with a constant voltage of 60 kV and a constant welding speed of 1200 mm/min. Based on the effects of the bead width and penetration depth from the welding current, the optimized welding current was selected, and the influence of the welding speed was then evaluated. The welding speeds considered were 300, 600, 900, and 1200 mm/min with a constant voltage of 60 kV. Figure 5 shows the variations in the bead width and penetration depth according to E-beam welding currents with a constant welding speed of 1200 mm/min. The weld penetration depth is increased as the weld current is increased, but the bead width shows a different tendency, as shown in Fig. 5. The bead width widens as the weld current is increased until 65 mA, and then narrows at the maximum weld current of 85 mA.

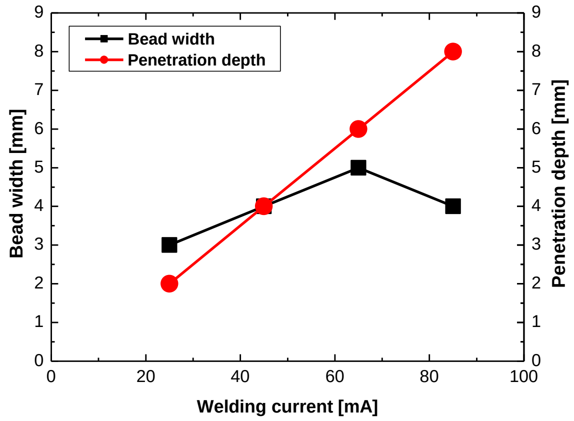

Fig. 5. The variation of the bead width and penetration depth according to the E-beam welding current at a constant welding speed of 1200 mm/min.

4. Conclusions

A fabrication procedure of a HCCR TBM sub-module was designed for a first wall, breeding zone including the side wall, and assembled sub-module by welding the first wall and breeding zone box. To establish and optimize the welding procedure in an E-beam weld from ARRA material, the variations of the bead width and penetration depth according to the welding current and welding speed were investigated using ARRA material. A plate for the test specimen to evaluate the welding characteristics was fabricated based on the optimized E-beam welding results.

REFERENCES

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[2] J. S. Yoon, S. K. Kim, E. H. Lee, S. Cho, D.W. Lee, Fabrication and integrity testing of a Korean ITER TBM FW mock-up in preparation for high heat flux test, Fusion Science and Technology Vol.64, p.657, 2013.