Fabrication of small mock-ups for the KO HCCR TBM

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1. Introduction

To develop next-generation technologies, one of the important objects of the 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 ITER [8]. The HCCR TBM is composed of four sub-modules and a back manipulator (BM). The fabrication technologies for HCCR TBM have been developed through the development of welding and joining technologies [9-13]. In addition, an advanced reduced activation alloy (ARAA) material has been developed and characterized for the HCCR TBM as a structural material, and used for a fabrication of the TBM mock-up. In a previous study, the fabrication method of the first wall was developed along with a half-scale mock-up using SS316L steel through a fabrication procedure [13].

In the present study, the fabrication procedure of the breeding zone including the side wall and a sub-module are introduced. Four small mock-ups were designed and fabricated to verify the fabricating procedure and method of the HCCR TBM sub-module. A distortion measurement using a distortion dial gage and gamma ray radiographic test to confirm the distortion rate after E-beam welding and joint integrity were carried out.

2. Fabrication procedure of the HCCR TBM sub-module and fabrication of small mock-up

2.1 Design and welding conditions of the small mock-ups

Four small mock-ups were designed and fabricated to verify the fabricating procedure and method of the HCCR TBM sub-module. Figure 1 shows the HCCR sub-module and breeding zone of the sub-module and four parts components marked with circles for manufacturing.

The small mock-ups in Fig. 2 show parts of the scaled-down sub-module. Part-A is a part of the scaled-down FW of a front plate with two cooling channels of 11 mm in width; Part-B is composed of two parts of the BZ components to verify the welding procedure; Part-C is composed of three parts of the BZ, SW of 25 mm thickness, and SW cover of 5 mm thickness; and Part-D is composed of FW, SW, and BZ components of 25 mm thickness plates. The small mock-ups have been designed. In addition, the E-beam and laser beam weld were carried out to optimize the welding procedure considering the weld speed and current to optimize the fabrication using ARAA plates from 5 mm to 25 mm in thickness.

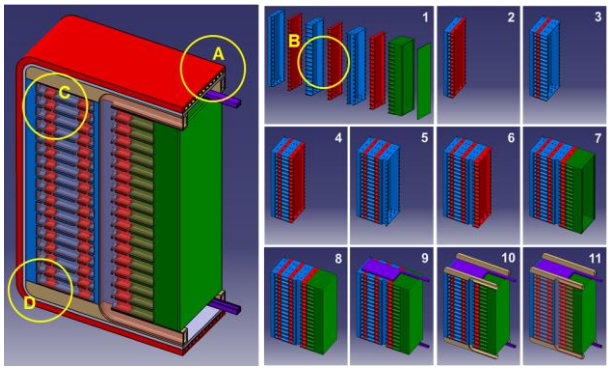

Fig. 1. Schematic diagram of HCCR TBM

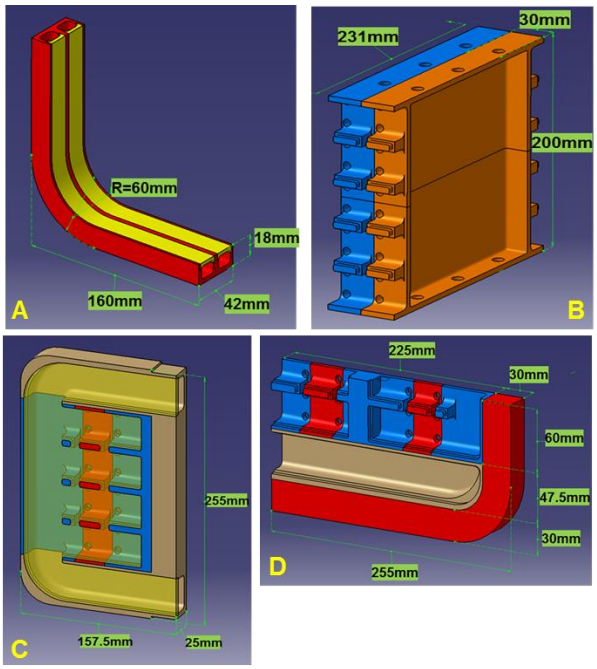

Fig. 2. Schematic diagram of the small mock-up

2.2 Fabrication of the small mock-ups

The manufacturing procedure of the HCCR TBM mock-up is as follows: 1) component machining, 2) welding, 3) post-machining, 4) NDT testing using radiography test (RT), and ultrasonic testing (UT). Hence, a leakage test, water pressure test, and so on will be carried out. Figs. 3 and 4 show the detailed manufacturing process. Figure 3 shows Part-B, which is BZ component of 5 mm thickness by E-beam welding. The fabrication procedure of BZ was processed as follows: first, the side plates were attached to each other, second, the E-beam weld was carried out at the top and bottom regions, third, the component was machined, and fourth, the E-beam weld was conducted in the side region again. Figure 4 shows Part-C, which is the fabrication of the BZ and SW, and was processed as follows: first, BZ and SW were machined, and second, E-beam welding was carried out.

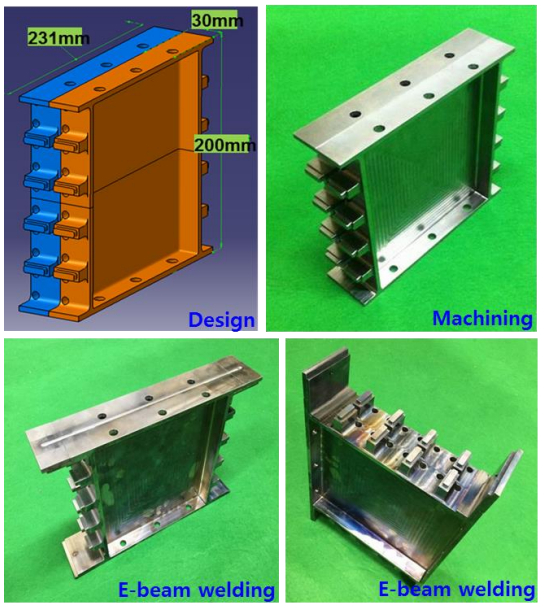

Fig. 3. Schematic diagram of the manufacturing process of the small mock-up of BZ (Part B)

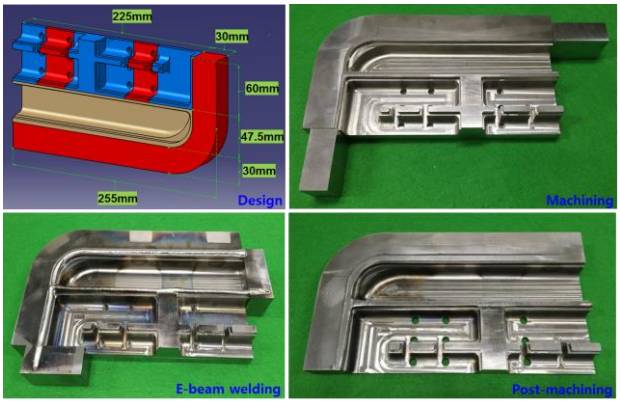

Fig. 4. Schematic diagram of the manufacturing process of the small mock-up of FW-SW-BZ (Part C)

2.3 Radiography test and distortion measurement

After E-beam weld and laser beam weld for the small mock-ups, gamma ray radiographic tests were carried out to investigate joint integrity. In addition, to verify the distortion after the E-beam weld, the amount of distortion was investigated using a distortion test dial gage. Figure 5 shows the measurement points of distortion in BZ small mock-up. The maximum distortion is -0.06 mm at the upper right and lower left edge regions, but can be an acceptable value.

To investigate the defect at the welding position of the small mock-up of FW-SW-BZ (Part C), the gamma ray radiographic test was carried. Figure 6 shows a photograph of the RT test result of the small mock-up of the FW-SW-BZ (Part-C), and it shows that there is no defect in the mock-up of FW-SW-BZ clearly. In addition, severe deformations are also not found in the RT test.

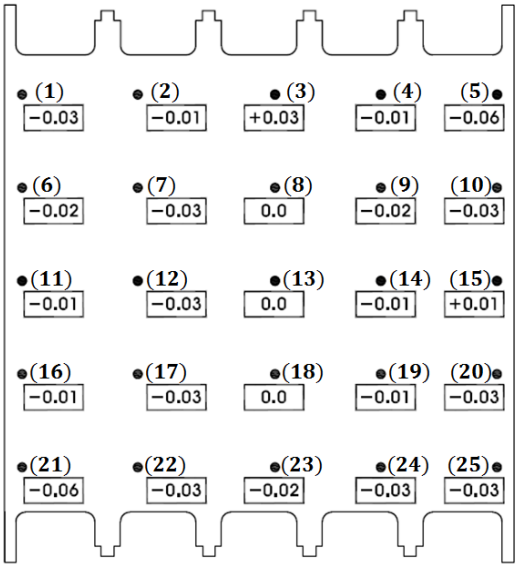

Fig. 5. Distortion measurement position in BZ side wall region

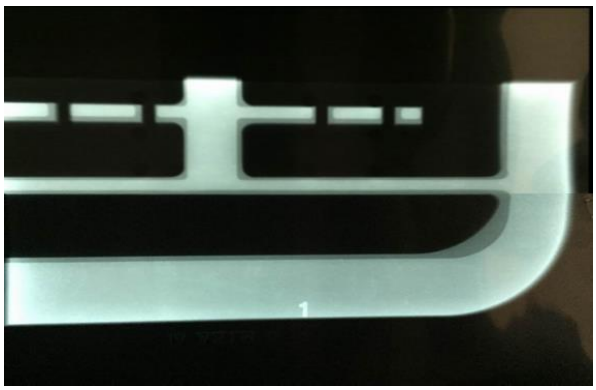

Fig. 6. Result of RT test in FW-SW-BZ region

3. Conclusions

A fabrication procedure for the manufacturing of the HCCR TBM sub-module was performed and small mock-ups were fabricated using an E-beam and laser beam weld to verify the manufacturing procedure and method of the HCCR TBM sub-module. To establish and optimize the welding procedure in an E-beam weld from ARAA material, the distortion and radiographic tests were carried out from the E-beam weld results. It could be noted that a small amount of distortion occurred, but the values are small enough to neglect for the fabrication. In addition, a helium leak test and water pressure test will be performed for verification of the fabricated small mock-ups.

Acknowledgments

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