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Fabrication of small mock-ups using E-beam welding for the KO HCCR TBM

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1. Introduction

A helium-cooled ceramic reflector (HCCR) breeding blanket has been developed in Korea as part of the Korean DEMO and fusion reactor [1]. It will be installed and tested in ITER in the form of a test blanket module (TBM). In Korea, an advanced reduced activation alloy (ARAA), which is a kind of RAFM steel, has been developed for the structural material of fusion reactor components including the HCCR TBM in ITER [2–5], and welding technologies have also developed in parallel, including electron beam (E-Beam) welding, tungsten inert gas (TIG) welding, and hot isostatic pressing (HIP) bonding with similar and dissimilar material weld considering the TBM features [6–8]. 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 [9] and four small mock-ups were designed and fabricated to verify the fabricating procedure and method of the HCCR TBM sub-module .

In the present study, small mock-ups were designed and fabricated to verify the fabricating procedure and method of the HCCR TBM sub-module through non-destruction and destruction tests.

2. Fabrication of small mock-ups to verify the procedure of the HCCR TBM sub-module

2.1 Progress of the FW small mock-ups fabrication

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 two parts components marked with circles for manufacturing. The small mock-ups in Fig. 2 and Fig. 3 show part 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 three parts of the BZ, SW of 25 mm thickness, and SW cover of 5 mm thickness plates. The small mock-ups have been designed and developed the fabrication process through various welding and manufacture methods. The fabrication process and methods of the small mockup of the FW have been developed and verified through various welding method and verification through destruction tests.

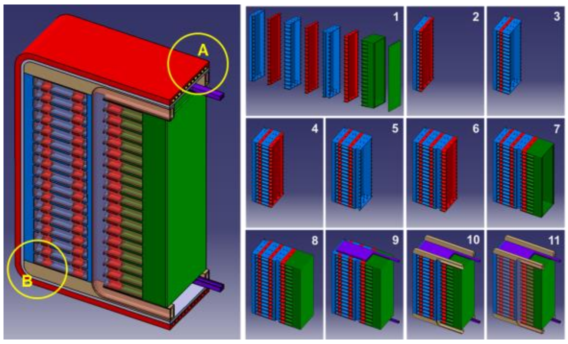
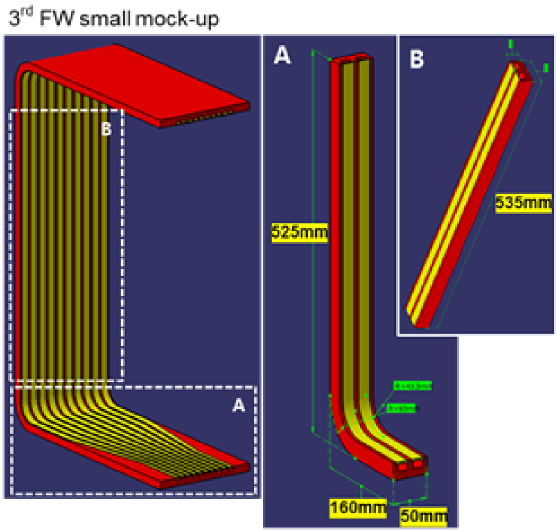


Fig. 1. Schematic diagram of HCCR TBM

a) 1st FW small mockup



2) 2nd FW small mockup

Fig. 2. Fabrication and verification of the FW small mock-up

2.2 Leak test and a water pressure test using BZ-SW(Part-B) small mock-ups

After an E-beam weld for the small mock-ups, ultrasonic test and gamma ray radiographic tests were carried out to investigate the joint integrity. In addition, to verify the distortion after the E-beam weld, the amount of distortion was investigated using a distortion test dial gauge. The maximum distortion is -0.06 mm at the upper-right and lower-left edge regions, which can be an acceptable value.

With the small mock-up of the BZ-SW (Part-B), a helium leak test was conducted at up to 1.0 x 10-7 Pa without any leakage. In addition, a water pressure test was carried out using the mock-up of the BZ-SW (Part-B) up to 22 MPa without failure, which is a similar pressure value as the operating pressure of 21.5 MPa considering the operation temperature of the HCCR TBM. Figure 4 shows the results of the water pressure test of the small mock-up of the BZ-SW (Part-B).

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

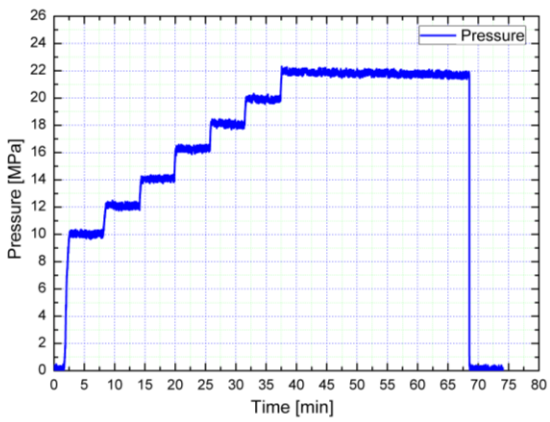


Fig. 4. Water pressure test of small mock-up (Part-B)

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 weld to verify the manufacturing procedure and method of the HCCR TBM sub-module. The distortion and radiographic tests were carried out to establish and optimize the welding procedure in an E-beam weld from ARAA material. A small amount of distortion occurred during the welding of the small mock-up, but the values were small enough to neglect for the fabrication. In addition, a helium leak test and water pressure test were performed for the small mock-up of BZ-SW. It was confirmed that the small mock-ups were successfully welded and fabricated through the helium leak test and water pressure test to check the bonding at the welding place.

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