Qualification Test for Korean Mockups of ITER Blanket First Wall

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1. Introduction

ITER First Wall (FW) includes the beryllium armor tiles joined to CuCrZr heat sink with stainless steel cooling tubes. This first wall panels are one of the critical components in the ITER machine with the surface heat flux of 0.5 MW/m^2 or above. So qualification program needs to be performed with the goal to qualify the joining technologies required for the ITER First Wall. Based on the results of tests, the acceptance of the developed joining technologies will be established. The results of this qualification test will affect the final selection of the manufacturers for the ITER First Wall.

2. Methods and Results

2.1 Manufacturing of mockup

The schematic diagram for the ITER first wall is in the Fig. 1.

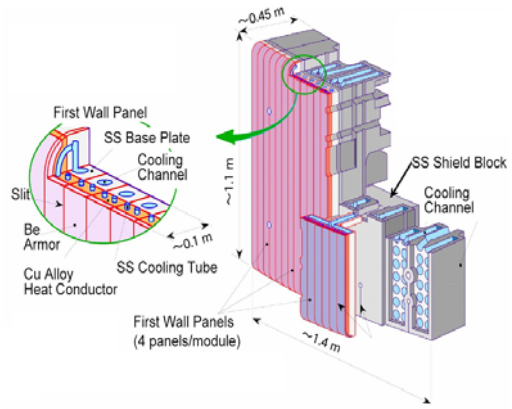

Fig. 1. Schematic diagram of ITER first wall.

The fabrication process of the KO qualification mock-up is shown in Fig. 2. The detailed procedure will be described in the following section.

For the CuCrZr and stainless steel, the canned materials are placed into the HIP furnace. HIP(Hot Isostatic Pressing) was conducted at 1050 °C and 100 MPa for 2 h with the heating rate of 5 °C/min and the furnace cooling. During the heating process, the temperature was hold at 900 °C for 210 min for pressure control and the homogenizing the materials. And in the case of Be to CuCrZr HIPping, the canned materials are placed into the HIP furnace. HIP was conducted at 580 °C and 100 MPa for 2 h with the heating rate of 4 °C/min and the furnace cooling. The canning plates were removed by electro-discharge machining. The surface of HIPped mock-up was mechanically machined to have a required surface roughness (R_a < 6.3 m). The materials were cleaned in the ethyl alcohol by using an ultrasonic cleaner. Fig. 3. shows the final mockup for the delivery to EU test site.

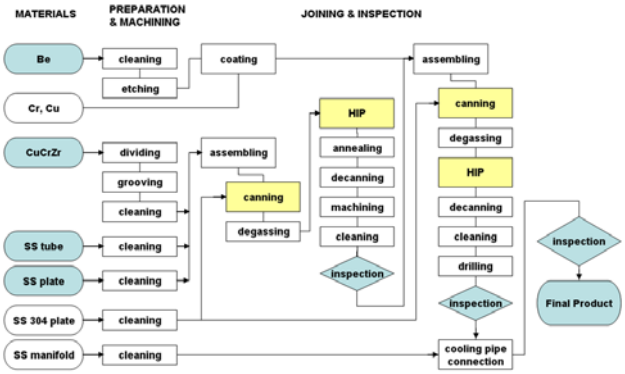

Fig. 2. Fabrication process of the qualification mockups.

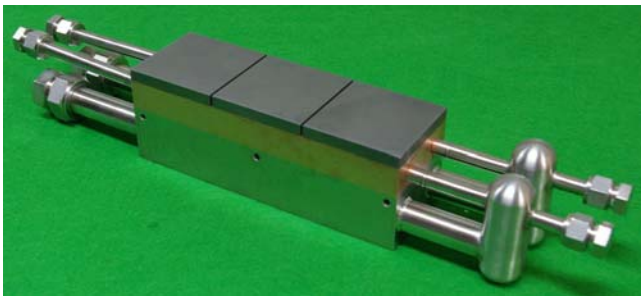

Fig. 3. Korean qualification mockup

2.2 Non-destructive and destructive test

Visual and dimension inspections were performed whenever needed in the fabrication process

Ultrasonic Test (UT) was performed with ultrasonic probes; a 5 MHz, 0.5 inch diameter, flat type for the CuCrZr/SS interface after a CuCrZr/SS HIPping. A 10 MHz, 0.25 and 0.5 inch diameter, flat type for the Be/CuCrZr after a Be/(CuCrZr/SS) HIPping. No defects were found in the interfaces.

He leak test was performed after a fabrication of the mock-up including the manifolds before a pressure testing. The He leak detector, Alcatel (Adixen) ASM 142, was used for this test. It was performed with both cooling paths; one up to 2.4x10^{-10} Pa.m^3/s (2.4x10^{-9}

mbar.l/s) and another up to $2.0x10^{-10}$ Pa.m^3/s ($2.0x10^{-9}$ mbar.l/s), which are much lower than the maximum allowable leak rate of $1.0x10^{-8}$ Pa.m^3/s.

Pressure test was carried out by using pressurized water after a completion of the He leak test up to 5 MPa for 2 hours with each cooling path. During the test, there was no pressure drop or water leakage.

Destructive tests for the qualification mockup were performed on a small mockup which was fabricated together with the qualification mockup. The small mockup for the destructive test has one Be tile with a dimension of 80x80x10 mm and no cooling pipes. It is assumed that the small mockup has the same properties as the qualification mockup since the two mockups are fabricated simultaneously with the same manufacturing process by using the same facilities.

The destructive test was focused on the evaluation of the joining properties. Be/CuCrZr and CuCrZr/SS joint specimens are machined from the small mock-up according the standard test method as shown in Fig. 4. The destructive tests of the CuCrZr/SS joint include a microstructure observation of an interface with an examination of the elemental distribution, tension test, and Charpy impact test. The destructive tests of the Be/CuCrZr joint include a microstructure observation of an interface with an examination of the elemental distribution, tension test, 4-point bend test, and shear test. The mechanical test will also be performed on the base metals for a comparison of the joint specimens. In addition, the destructive tests of the CuCrZr alloy have been also included tensile tests at room temperature /250 °C and fatigue test.

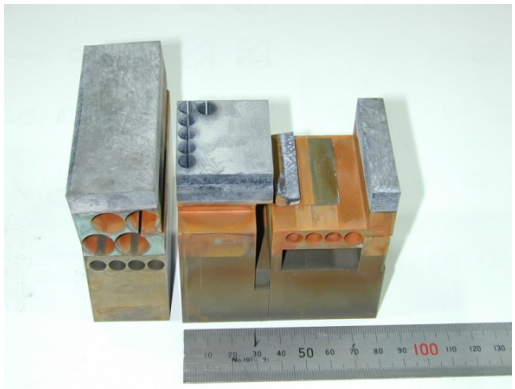

Fig. 4. Small mockup simultaneously fabricated with the qualification mockup after extracting all kinds of samples for the destructive tests.

2.3 Qualification test for first wall mockup

For the qualification test, 4 mockups were manufactured simultaneously in KAERI. Two mockup were delivered to US and EU, and the others were tested in KAERI, KoHLT-1 facility.

In US, Sandia national laboratory, test round consists of tests on four mockups, from Korea, Japan, Russia, China. The normal cycle is based on an expected heat flux of 0.5 MW/m^2 for 100 s. The normal cycle was modified to provide an optimum cycle for the electron gun where the beam is not shut off after each cycle, but can heat up a second mockup during the cool down time of the first mockup. Calculations by the International Organization (IO) on the stresses at the Be/CuCrZr interface were used to determine test conditions and a heat flux of 0.7 MW/m^2 was determined for a 48 s on/48 s off cycle. The heat flux was then increased by a factor of 1.25 as a safety margin to 0.875 MW/m^2.

The MARFE(Multifaceted asymmetric radiation from the edge) condition is 10 s of 1.75 MW/m^2. The MARFE condition is expected to occur 1,000 times during the life of the ITER machine. The equivalent cycling at the US facility was found to be 20 s on/20 s off of 1.4 MW/m^2 of heat. These US tests take place in the Plasma Material Test Facility in the EB-1200 system.

And EU test was divided with Czech and Germany, normal test 0.625 MW/m^2 was test in Czech, NRI research center, and MARFE test was in Germany, FZJ Juelich research center.

Some test cycle of US facility shows in Fig. 5. This image is the infrared camera of US Sandia lab.

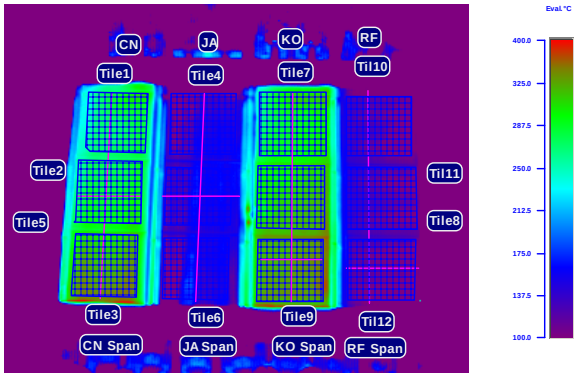

Fig. 5. Infrared image during heating of mockups 1(China) and 3(Korea) at end of cycle 2382 in US test.

3. Conclusions

ITER first wall mockups to establish the manufacturing capability of Korea were passing the international qualification test in the each test site, August in US, September in EU. Two Korean mockups were endured the 12,000 normal cycles, and 1,000 MARFE cycles. We have passed qualification test to be performed with the goal to qualify the joining technologies required for the ITER First Wall. Korea development team shows their technical ability to perform the manufacturing with required quality.