Manufacturing and High Heat Flux Test of Beryllium Slit Mockups for ITER First Wall Qualification

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1. Introduction

The slit grooving mockups with 80 mm x 80 mm Be tile were fabricated to perform high heat flux test for ITER first wall qualification, which includes the beryllium armor tiles joined to CuCrZr heat sink with stainless steel cooling tubes, and was slit to make same size of four parts. These tests were performed in the Korea heat flux test facility (KoHLT-1) with the maximum surface heat flux of 1.25 MW/m^2 to qualify the joining technologies required for the ITER First Wall. As a result, the acceptance of the developed joining technologies will be established for the ITER first wall qualification.

2. Methods and Results

2.1 Manufacturing of mockup

The schematic diagram and illustration for the ITER first wall is in the Fig. 1. The semi-prototype is a part of main first wall frame which has three double-fingered panels (lower part of Fig. 1). The standard slit mockups with 80 mm x 80 mm Be tile divided by narrow slit were fabricated to qualify our HIP (Hot Isostatic Pressing) technology.

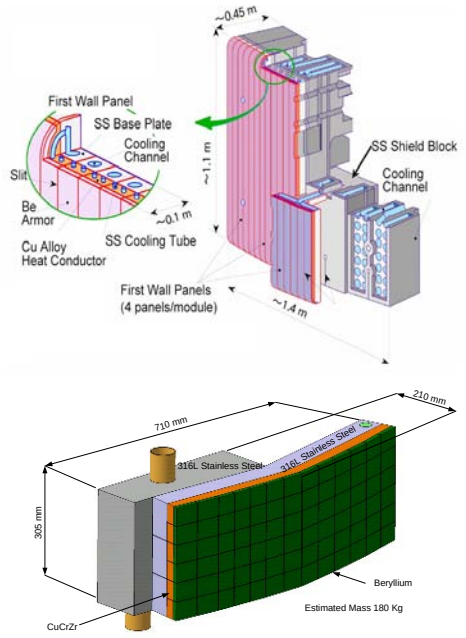

Fig. 1. Schematic diagram of ITER first wall (upper) and semi-prototype (lower).

The fabrication process of the mockups is shown in Fig. 2. For the CuCrZr and stainless steel, the canned materials were placed into the HIP furnace. HIP was conducted at 1,050 °C and 100 MPa for 2 hours with the heating rate of 5 °C/min and the furnace cooling. During the heating process, the temperature was held at 900 °C for 210 min for pressure control and the homogenizing of the materials. And, in the case of Be to CuCrZr HIPping, the canned materials were placed into a HIP furnace. HIP was conducted at 580 °C and 100 MPa for 2 hours with the heating rate of 4 °C/min and the furnace cooling. The canning plates were removed by electro-discharge machining. The materials were cleaned in ethyl alcohol by using an ultrasonic cleaner. Fig. 3 shows the final assembly mockup for installation to KoHLT-1. To simulate the manufacturing procedure of ITER first wall semi-prototype, slit mockups were fabricated as shown in Fig. 3, these mockups have four pieces of Be tiles.

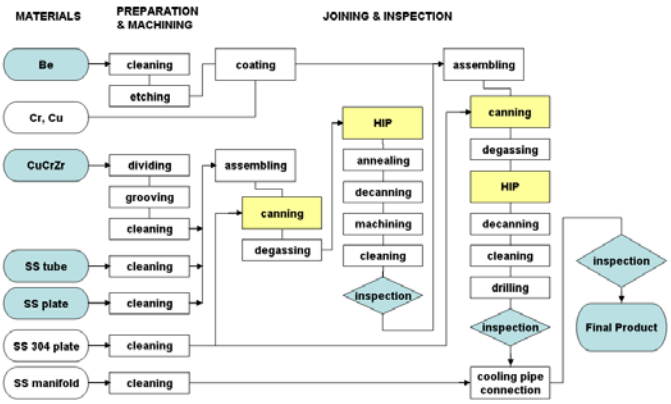

Fig. 2. Manufacturing procedure of ITER first wall mockups.

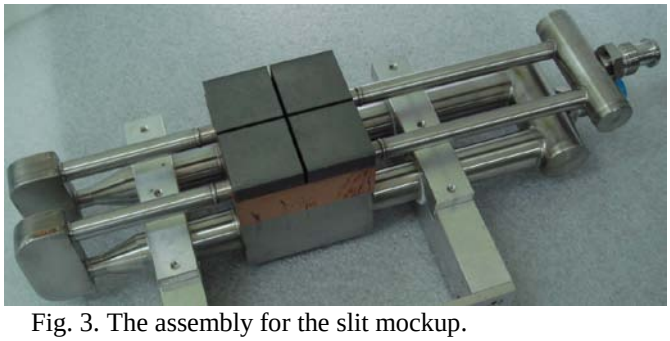

Fig. 3. The assembly for the slit mockup.

2.2 Non-destructive test

Ultrasonic Test (UT) was performed with ultrasonic probes; a 10 MHz, 0.25 inch diameter, flat type (non-focused) for the Be/CuCrZr. The sensitivity is 74 dB for UT instrument, Panametrics 5800. There were no defects in the interfaces, Fig. 4 shows the result of the ultrasonic test for standard mockups.

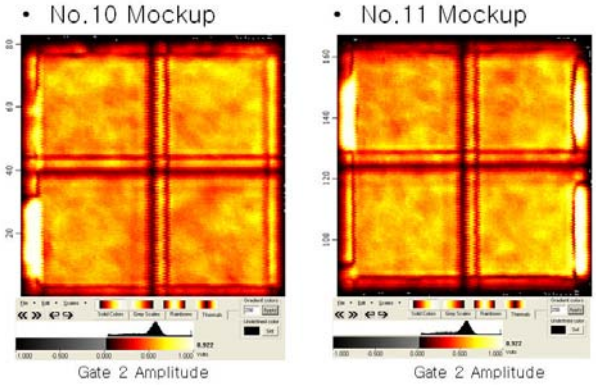

Fig. 4. The results of ultrasonic test for the slit mockups.

2.3 High heat flux test for standard mockups

Preliminary thermal and mechanical analysis were carried out to simulate the test conditions and to determine the number of cycles for fatigue lifetime of mockups. In our KoHLT-1 facility, the normal heat cycle was based on an expected heat flux of 1.25 MW/m^2 for 300 seconds, and each mockup must endure the 1,000 normal heat cycles in this heat flux in accordance with the mechanical simulation. In the cyclic heat flux tests, maximum surface temperature of Beryllium tiles was below 673 K.

For the high heat flux test, four mockups (#S881-08/09/10/11) were manufactured simultaneously in KAERI. Two mockups were the normal standard mockups, and the others were slit mockups. In our KoHLT-1 facility, the normal cycle was based on above heat flux condition.

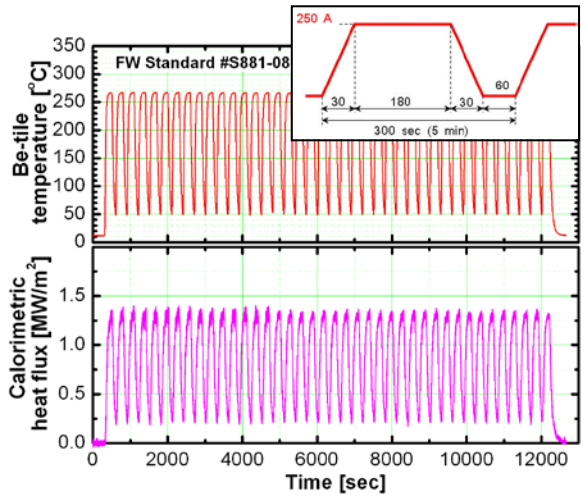

Fig. 5. The result of high heat flux test (#S881-08).

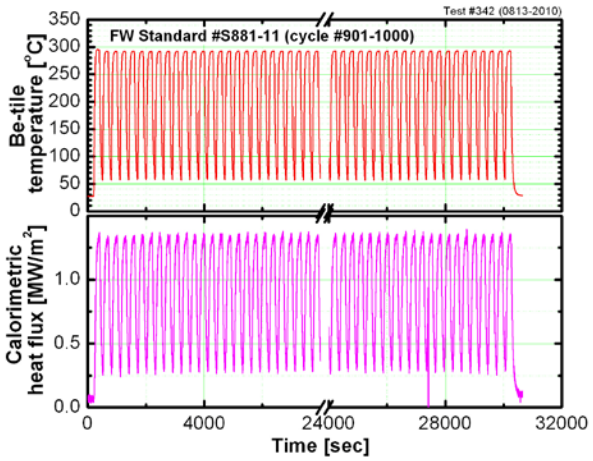

Fig. 6. The result of high heat flux test (#S881-11).

Fig. 5 and 6 illustrate the cyclic heat flux and surface temperature in the Be tile of standard mockups (S/N S881-08, 11). Test facility and mockups are shown in Fig. 7, after test, change of the surface condition is also shown in this picture.

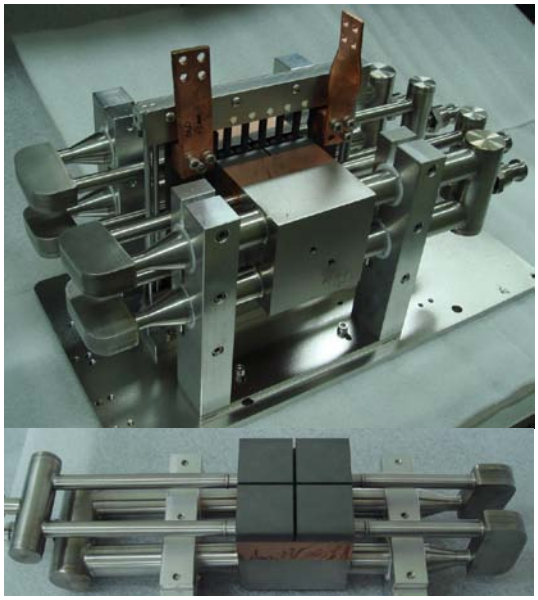

Fig. 7. The slit mockup installed in the KoHLT-1.

3. Conclusions

ITER first wall mockups with slit to establish the manufacturing capability of semi-prototype in Korean R&D team were fabricated with divided Be tile. Each mockup must endure the 1,000 normal cycles in the maximum heat flux of 1.25 MW/m^2 by using KoHLT-1 test facility. These tests have been performed to qualify the joining technologies required for the ITER first wall and semi-prototype. As a result of these high heat flux tests with the acceptance criteria of ITER first wall, the manufacturing technologies of KO standard mockups will be utilized to develop the intrinsic semi-prototype by the international qualification procedure.