Current Status on the Fabrication Technology Development for ITER Blanket First Wall in Korea

Dong Won Lee[a)], Young Dug Bae, Suk Kwon Kim

[a)]Korea Atomic Energy Research Institute
Deokjin-dong, Yuseong-gu, Daejeon, 305-600, Republic of Korea
E-mail: dwlee@kaeri.re.kr

1. Introduction

Korea had responsibility for the procurement of the International Thermonuclear Experimental Reactor (ITER) blanket modules 1, 2 and 6 as a ITER participant. Now, our responsibility was changed from the procurement to only the development of fabrication technology including the international qualification. Each blanket module is composed of first wall (FW) panel and shield block. Especially for the FW, it is an important component which faces the plasma directly and it is subjected to high heat and neutron loads. The FW is composed of a beryllium(Be) layer as a plasma facing material, a copper alloy(CuCrZr) layer as a heat sink and type 316L authentic stainless steel(SS316L) as a structure material. For the joining of the above three metals, Hot Isostatic Pressing(HIP) has been developed including the Post HIP Heat Treatment(PHHT) in Korea. For the verification of the joining integrity, high heat flux(HHF) test for loading the cyclic heat load has been performed with foreign and domestic facilities. In the present paper, the development procedure and future plan was introduced.

2. Development of the fabrication technology

The optimum joining condition of a HIP for the ITER FW has been developed with the conditions of 550 ^{O}C, 100 MPa, and 2 hour for Be/CuCrZr and of 1050 ^{O}C, 100 MPa, and 2 hours for CuCrZr/SS316L[1-5] including PHHT, as show in Figure 1. For joining Be to Cu alloy, several interlayers have been proposed such as Cr/Cu, Ti/Cu, Ti/Cr/Cu and tested with fabricated mock-ups with the various HIP conditions using HHF test facilities from 2005, as shown in Table 1. In these experiences, we fabricated 80x80x3 mock-ups with Cr/Cu interlayer among them and they were passed in the international qualification test in EU and US, respectively and the fabrication technology in Korea was proven with these results in the last year. We are now preparing the next qualification program for semi-prototype considering the design change of ITER blanket FW and enhanced surface heat flux.

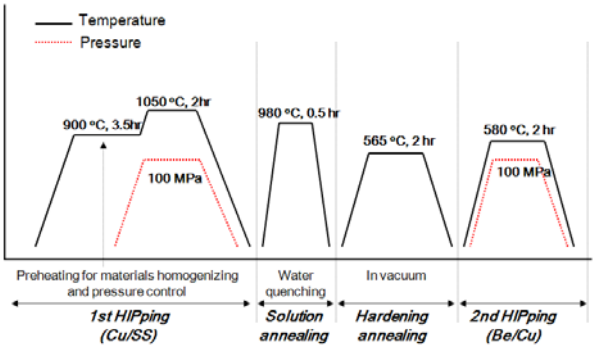
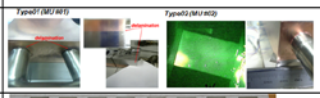
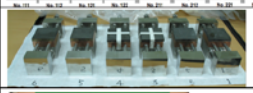
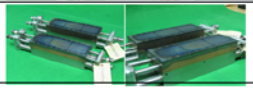


Figure 1 HIP and PHHT conditions for KO blanket FW fabrication

Table 1 HHF tests for developing the joining technology

Mock-ups	Test dates	Facilities	Test conditions & results	Tested mock-ups
50x100 Cu/SS	2005.12 - 2007.05	JEBIS (Japan)	3.2 & 5.0 MW/m^2 Developing and verifying Cu/SS joining methods	
50x50x1 Be/Cu	2007.08 - 2007.09	TESEFEY (Russia)	3.2 & 2.5 MW/m^2 Testing the Interlayer(Cr/Cu, Ti/Cu, Ti/Cr/Cu) & HIP temperature (580 °C, 620 °C)	
80x80x1 Be/Cu/SS	2008.04 - 2008.06	JUDITH (Germany)	0.55 to 1.5 MW/m^2 Testing Interlayers (Cr/Ti/Cu, Ti/Cr/Cu, Ti/Cu)	
80x80x3Be/Cu/SS	2008.04 - 2008.05	TESEFEY (Russia)	1.5 & 2.0 MW/m^2 Testing Interlayer(Cr/Cu, Ti/Cu, Ti/Cr/Cu) and 3-tile MU	
35x35x3 Be/Cu/SS	2008.12 - 2009.01	KoHLT-1 (Korea)	1.0 & 1.5 MW/m^2 Testing Interlayer(Cr/Cu, Ti/Cu, Ti/Cr/Cu) and 3-tile MU	
80x80x3 Be/Cu/SS	2008.09 - 2009.04	KoHLT-1 (Korea)	0.625 MW/m^2 Testing preliminary FWQMs	
80x80x1 Be/Cu/SS	2009.10 - present	KoHLT-1 (Korea)	0.5 to 1.5 MW/m^2 Developing Inherent joining methods	

3. Development of the HHF test facility

Since a HHF test is essential for investigating the thermo-mechanical performance of a FW including the integrity of the HIP bonded interfaces, the fabricated mock-ups were tested at Korea Heat Load Test (KoHLT) facilities[6]: The KoHLT-1 and -2, which consist of a target assembly including a target mount and graphite heater, test chamber, DC power supply, water cooling system, data acquisition system, and auxiliary system(beryllium evacuation system, helium gas feeding system, diagnostics system). Photographs and design parameters of them were shown in Figures 2 and 3, and Table 2.

Figure 2 Photograph of KoHLT-1

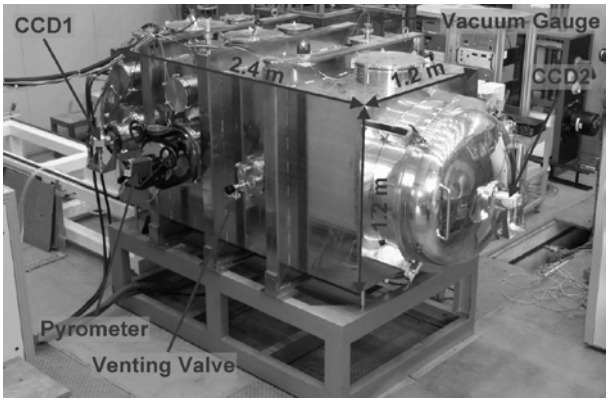


Figure 3 Photograph of KoHLT-2

Table 2 Developed facilities for HHF tests in Korea

Facility	KoHLT-1	KoHLT-2
Major target	small to middle size PFC with Be	Large size PFC
Heat flux with max. target area	0.7 MW/m² (244x80 mm²)	0.46 MW/m² (700x100 mm²)
Heating element	Graphite panel (0.25Ω)	Graphite panel (0.5Ω)
Power supply	40 kW (DC 100V, 400A)	80 kW (DC 200V, 400A)
Test chamber	Box-type chamber (0.3x0.3x1.2 m³)	Box-type chamber (1.2x1.2x2.4 m³)
Filling gas	He	He
Cooling water	25 °C, 0.1 MPa	25-100 °C, 3 MPa

4. Future plan

As mentioned before, the 2nd qualification has been prepared against more complex geometries and higher heat flux, which will be reflect the changed blanket FW design, as shown in Figure 4. Since the target heat flux will be increased up to 5 MW/m^2, we will develop a new test facility, which use electron beam with the power of 300 kW.

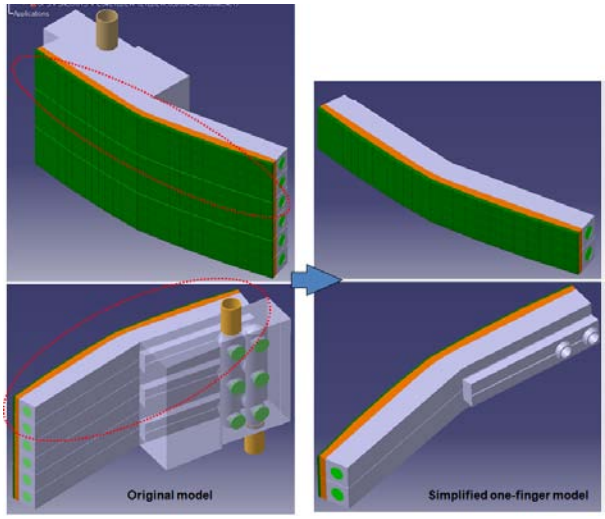


Figure 4 Modeling of the semi-prototype for ITER blanket FW

5. Conclusions

In Korea, we developed the fabrication technology for ITER blanket FW using the HIP and it was proved through the 1st qualification test. In this procedure, we developed two HHF test facilities (KoHLT-1 and -2) using the radiation heating with graphite heaters. The 2nd qualification test has been prepared focusing on the fabrication methods and HHF test.

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