Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Preparation of High Heat Flux Test with Be/Cu and Be/Cu/SS Mock-ups for the ITER First Wall

[a)]*Dong Won Lee, Young Duk Bae, Bong Geun Hong, Jeong Yong Park, Yong Hwan Jeong, Byung Kwon Choi, and Jong Hyuk Lee*
[a)]*Korea Atomic Energy Research Institute*
Deokjin-dong, Yuseong-gu, Daejeon, 305-600, Republic of Korea
E-mail: dwlee@kaeri.re.kr

1. Introduction

The first wall (FW) of the International Thermonuclear Experimental Reactor (ITER) is an important component which faces the plasma directly and therefore, 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. To fabricate the FW, the Hot Isostatic Pressing (HIP) bonding method has been investigated. Surface heat flux of the FW is about 0.3 MW/m^2 and the volumetric heating in the FW is in the order of 15-20 MW/m^3 due to a neutron wall loading [1]. To investigate the thermo-mechanical performance of the FW, including the integrity of the HIP bonded interfaces, high heat flux (HHF) tests are essential. This work has three steps; Cu/SS mock-ups test at JEBIS (JAEA electron beam irradiation stand), Be/Cu mock-ups test in TSEFEY-M facility (Russia), and Be/Cu/SS mock-ups test in EB1200 (US). Some results for Cu/SS mock-up tests were already introduced [2] and other test are being prepared through preliminary analysis to determine the test conditions and mock-ups were designed and being fabricated.

2. HHF test of Be/Cu mock-ups

The optimum joining condition of a HIP for the ITER FW has been developed by using Be of S-65C grade, CuCrZr, and SS316L. Here, CuCrZr/SS316L (tube and block) and Be/CuCrZr including SS316L tube mock-ups were fabricated to investigate their integrity through several tests. They were successfully HIPped at 550 ^{O}C, 150 MPa, and 1 hour for Be/CuCrZr and at 1050 ^{O}C, 100 to 150 MPa, and 2 hours for CuCrZr/SS316L as shown in Fig. 1. Figure 2 shows one of fabricated mock-ups and their dimensions are 50 mm long, 50 mm wide, and 32 mm thick (10 mm of Be tile and 22 mm of Cu alloy). Two circular tubes (10mm ID) are inserted for a cooling. Microstructure observation and mechanical tests were performed to confirm the joining technology [3].

HHF test for the Be/Cu mock-up will be performed in the same way as that for the Cu/SS mock-up [2]. The test conditions were found from the analysis with ANSYS-10 with a 2D model as shown in Fig. 3; the heat flux is assumed to be 3.2 MW/m^2 so as not to exceed the Be temperature limitation; water cooling conditions are determined from the TSEFEY-M facility conditions (25 ^{o}C and 2 MPa). For enough cooling, water speed is assumed to be 10 m/sec and then the heat transfer coefficient (HTC) in the tube is 31625 W/m^{2}K which was obtained from CFX-10 simulation. Figure 4 shows the temperature and strain distribution by an analysis when the duration was 80 sec (40 sec heating and 40 sec cooling for saturated condition). Since the expected number of cycles for CuCrZr is 535 when the von Mises strain is 0.6206 %, the test will be performed more than this number of cycles [4].

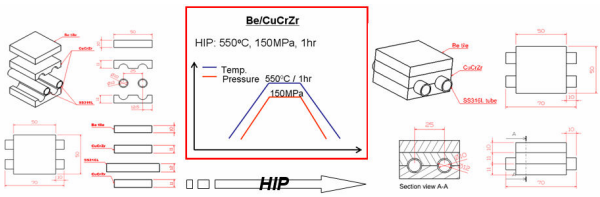

Figure 1 Schematic of the Cu/SS mock-up and its fabrication procedure

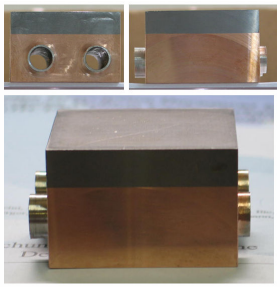

Figure 2 Fabricated Be/Cu mock-up

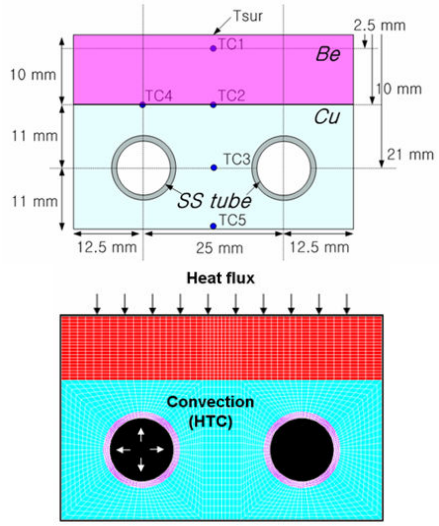

Figure 3 Analysis model and conditions of ANSYS-10

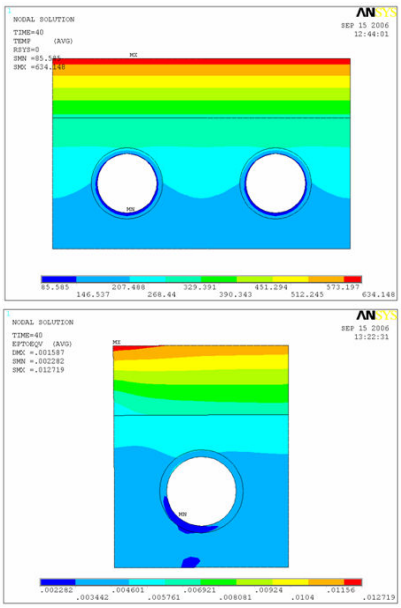

Figure 4 Temperature and strain distribution at heating time (40 sec)

3. HHF test of Be/Cu/SS mock-ups

For the HHF test of Be/Cu/SS mock-ups in EB1200, the mock-ups were designed to have three Be tiles of 50 mm long and 50 mm wide as shown in Fig. 5. Two circular tubes (10mm ID) are inserted for a cooling in Cu block and two circular holes (22 mm ID) in SS block. HHF test for the Be/Cu/SS mock-up will be performed in the same way as that for the previous mock-ups. The heat flux was assumed to be 2.5 MW/m^2 so as not to exceed the Be temperature limitation; water cooling conditions were determined from the EB1200 facility conditions (25 ^{o}C and 2 MPa). For enough cooling, water speed was assumed to be 14.1 m/sec and 2.9 m/sec at SS tube and SS holes, respectively. In this speed, HTCs by CFX-10 were 59182 W/m^{2}K and 13488 W/m^{2}K, at SS tube and SS holes, respectively. Figure 6 shows the temperature and strain distribution by an analysis when the duration was 160 sec (80 sec heating and 80 sec cooling for saturated condition). When the von Mises strain is 0.6206 % in this time, the expected number of cycles for CuCrZr is 600 and the test will be performed more than this number of cycles [4].

4. Conclusions

HHF test of a HIP bonded mock-ups have been prepared to be performed in TSEFEY-M facility for Be/Cu mock-ups and in EB1200 for Be/Cu/SS ones. The test conditions such as heat flux, coolant speed, duration time, and required number of cycles to failure were determined through thermo-mechanical analysis with ANSYS-10 as summarized in table 1. The Be/Cu mock-ups were already fabricated and Be/Cu/Ss ones are being fabricated.

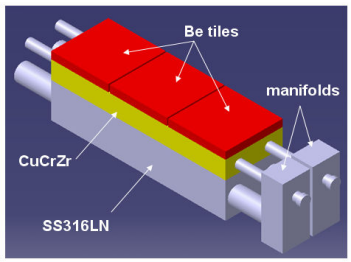

Figure 5 Design of Be/Cu/SS mock-up

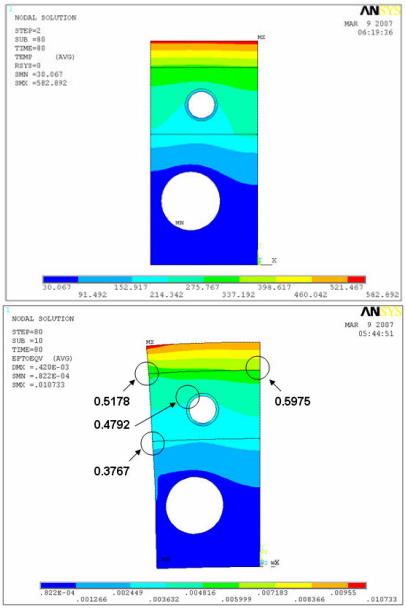

Figure 6 Temperature and strain distribution at heating time (80 sec)

Table 1 HHF test conditions and analysis results

Items	Be/Cu mock-up	Be/Cu/SS mock-up
Heat flux	3.2 MW/m^2	2.5 MW/m^2
Coolant speed	10.0 m/s at SS tubes	14.1 m/s at SS tubes 2.9 m/s at SS holes
Duration time (heating/cooling)	40sec/40sec	80sec/80sec
Max. T at Be surface	634 ^{o}C	583 ^{o}C
von Mises Strain at Be/Cu interface	0.6206 %	0.5975 %
Required no. of cycles	~ 535	~ 600

REFERENCES

[1] A. Cardella, et al, Technical Basis for the ITER EDA plasma facing components, Fusion Eng. Des. 39-40 (1998) 377-384

[2] Dong Won Lee, Young Duk Bae, Bong Guen Hong, Jeong Yong Park, and Yong Hwan Jeong, "High Heat Flux Test of a HIP Bonded Cu/SS Mock-up for the ITER First Wall," Journal of Korean Vacuum Society, Vol.15, no.3, pp37-44, May 2006.

[3] J. Y. Park et. al., "Optimization of joining condition for ITER first wall fabrication," Journal of the Korean Physical Society, Vol.49, pp S442-S446, Dec. 2006.

[4] ITER Material Properties Handbook, File code : ITER-AA02-2402