Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

Design and Analysis of the Korean Small Semi-prototype Mock-up for the 2nd Qualification of the ITER Blanket First Wall

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1. Introduction

Since the blanket First Wall (FW) of the International Thermonuclear Experimental Reactor (ITER) is subjected to a high heat and high neutron loads, it is one of the most important components. It 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. The joining of the three different metals is the key issue to be solved. And more, the peak heat load was assumed to be 0.5 MW/m^2 in the initial design of the FW, but it was changed to be up to 5 MW/m^2, recently. Therefore, the FW panel design has been changed for enhancing the cooling and ITER Organization will provide the proposed design.

In Korea, the joining method has developed and it was proved through the several mock-up fabrication and high heat flux tests for confirming the joining integrity. Some of them were tested in the foreign facilities such as JEBIS at JAEA in Japan, TSEFEY at Efremov in Russia, and JUDITH at FZJ in Germany, and others were tested in our own facilities such as KoHLT-1 and -2. And finally, the 1st qualification was passed, in which two 80x80x3 Be/Cu/SS mock-ups were tested under 0.625 and 0.875 MW/m^2 heat fluxes for 12,000 cycles and then tested under 1.75 and 1.40 MW/m^2 heat fluxes for 1,000 cycles at FZJ and SNL, respectively [1-8].

Currently, the 2nd qualification program was started and the semi-prototype should be fabricated by the end of 2011 for testing under 5.0 MW/m^2 heat flux for certain number of cycles. In order to prepare the semi-prototype, several fabrication methods should be developed through the fabrication and test with the several mock-ups. In the present study, small Be mock-up was fabricated as the first step for the preparation. It was fabricated according to the designs considering the currently modified design of the FW [9-10]. In the present paper, the fabrication objectives, methods, results and related tests were introduced.

2. Fabrication of the small Be mockup and its analysis

According to the semi-prototype design, the small Be mock-up was designed as shown in Fig. 1. Six Be tiles (52x52x10.5) were joined to Cu block by the hot isostatic pressing (HIP) with the following developed conditions; 580 ^{o}C and 100 MPa for 2 hours using the interlayer of 1μmTi/0.5μmCr/5μmCu and then the tiles were cut to have 2 mm gaps between tiles. In the original fabrication, Cu/SS should be joined by HIP before Be joining, but EB welding was used for joining for easier fabrication in the present study since the joinint integrity between Be and Cu was focused.

For confirming the joining integrity, high heat flux (HHF) test has been prepared. Preliminary analysis for determining the test conditions and manifold welding to install the test facility, KoHLT-1 were performed. In the changed operation conditions of the ITER, the peak surface heat flux of the FW is about 5.0 MW/m^2 but we considered the possible loading heat flux by the facility because the joint integrity is only concern in the present study. The analysis was performed with ANSYS-CFX and -mechanical using the test conditions, as shown in Table 1. Due to the bended shape of the mock-up, the test should be performed as follows; first six tiles at the inlet region (1-3 in Fig. 1) will be heated after then, other six tiles at the outlet region (4-6 in Fig. 1) will be tested. This test procedure is the same as the test plan of the original semi-prototype.

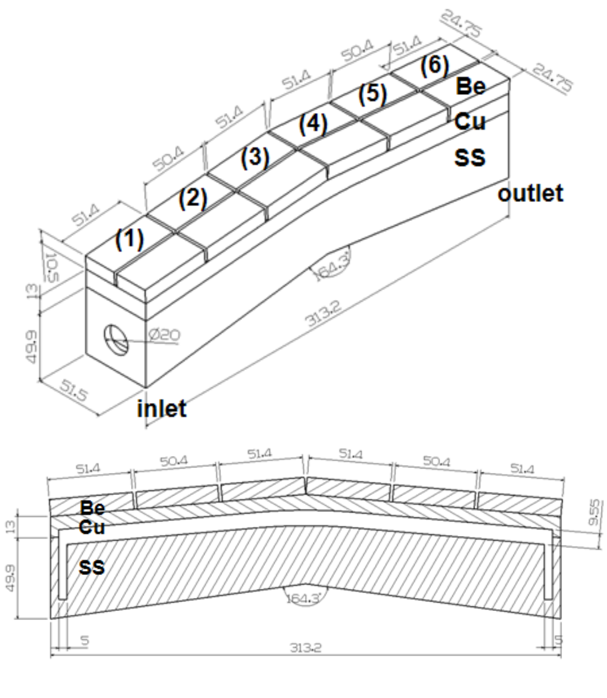

Fig. 1 Nodalization of the GAMMA input and a comparison with the experimental data

Table 1 Simulation conditions for small Be mock-up

Items	Conditions	Remark
Surface heat flux [MW/m^2]	0.7/1.0/1.5	3 cycles per each heat flux
Heater location	Inlet/outlet region	Separate simulation
Total water flow	0.3 kg/sec 0.96 m/sec inlet 0.2 m/sec center	0.584 kg/sec with SP
Inlet water conditions	0.2 MPa, 20 ^{o}C	Test conditions
Duration time	30 sec heater-on 180 sec holding 30 sec heater-off 60 sec cooling	300 sec duration time

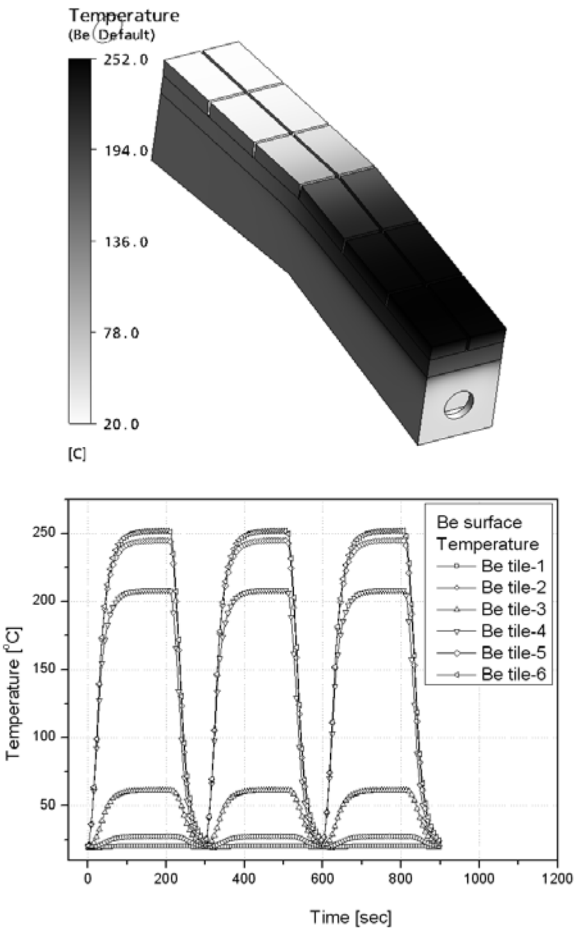

Fig. 2 Temperature distribution and evolution when heater is located in the outlet region

In the analysis, the above consideration was also used. Solid and liquid meshes were separately generated and combined. Total number of elements was 614,415 and temperature-dependent physical properties were used for each material. Figure 3 shows the temperature distribution at heating phase (810 sec) and evolutions for 3 cycles when the 0.7 MW/m^2 heat flux was loaded in case that the heater is located in the outlet region as shown in Fig. 2. The maximum Be temperatures reached up to 198.1 ^{o}C and 252.0 ^{o}C when the heater is located in the inlet and outlet region, respectively. With the obtained temperature distribution at 810 sec, the deformation and von Mises strain were calculated by ANSYS-mechanical. From these strain, the number of cycles to failure was predicted for Cu alloy, CuCrZr-ITER grade. According to the analysis results, the test will be performed according to the conditions described in Table 1 for 29,000 cycles.

4. Conclusion

In order to prepare the second qualification of the blanket FW for ITER, in which a semi-prototype of the FW should be submitted by the end of 2011, fabrication methods for complex geometry and analysis have been performed. The small Be mock-up was fabricated and the HHF test was being prepare by performing the preliminary analysis to determine the test conditions. It was successfully fabricated and the test conditions were obtained; 0.7 MW/m^2 heat flux and 29,000 cycles.

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