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High Heat Flux Test of the ITER FW Semi-prototype Mockups

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1. Introduction

As a procurement party of the ITER (International Thermonuclear Experimental Reactor) blanket project, we have to pass the qualification program which comprises two distinct phases; Phase 1 is about qualifying joining techniques, and phase 2 covers production scaled up component which is so called 'semi-prototype' and the enhanced heat flux qualification tests. For the phase1 qualification, we have constructed the FWQMs (First Wall Qualification Mockups) and already passed the qualification thermal fatigue tests [1] organized by the IO (ITER Organization). The tests were performed at the EB-1200 [2] in the USA and at the BESTH [3]/JUDITH-2 [4] in the EU. For the phase 2 qualification, the semi-prototype design will be provided by the IO. Even though the design has not fixed yet because the generic design of the first wall is not fixed, it shall comprise a minimum of 3 full length pairs of first wall fingers. We designed and fabricated two semi-prototype mockups which have a full length pair of first wall finger. The two mockups were designed to have different types of the cooling channels; one has a plain rectangular cross-section and the other has a hypervapotron type cooling channel. In order to compare the cooling capability of the two types, we performed high heat flux tests of the two mockups at the KoHLT-2.

2. Design and Fabrication of the Semi-prototype Mockups

We designed the semi-prototype mockups which have the cross-sections as shown in Fig. 1. Each mockup composes of a Cu-alloy heat sink and a SS316L block which are bonded by a brazing method. In order to compare the cooling performance, we fabricated two mockups which have different cooling channels shown in Fig. 1. The left one (labeled by N-01) has a plain rectangular cooling channel, and the right one (E-01) has a hypervapotron type cooling channel to have an enhanced cooling capability. The length of the mockup is 700 mm which is identical to the real first wall finger. Figure 2 shows a part of the Cu-alloy heat sink which has hypervapotron type cooling channel. Fabricated two mockups are shown in Fig. 3. They have identical dimension to the real first wall finger but the mockups don't have Be tiles on the heat sink, and a toroidal curvature. Three K-type thermocouples are mounted from rear side of each mockup. The thermocouples extend to 5 mm below the front surface.

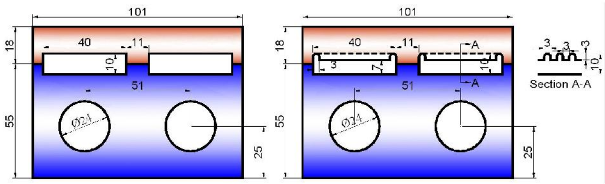

Fig. 1. Cross-sectional view of the semi-prototype mockups. The left one has a plain rectangular cooling channel, and the right has a hypervapotron type channel.

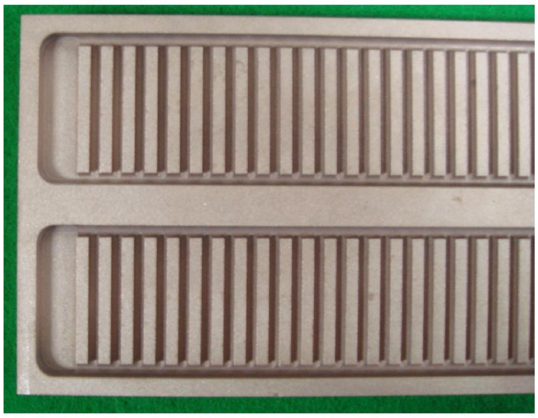

Fig. 2. Fabricated Cu-alloy heat sink prior to the bonding, which has a hypervapotron type cooling channel.

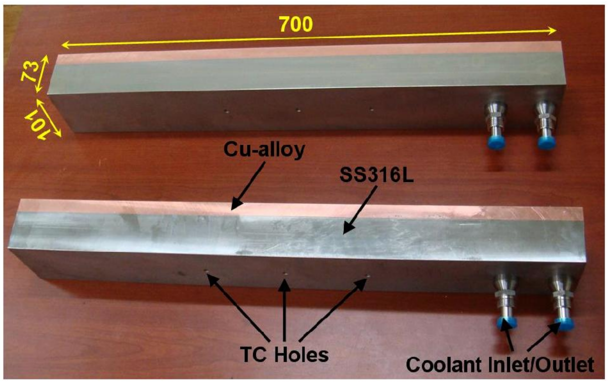

Fig. 3. Fabricated two mockups.

3. Heat Flux Test of the Mockups

Prior to the heat flux test, we performed the CFX analysis to calculate the temperature profiles of two mockups for the KoLHT-2 test conditions; the cooling water has an inlet temperature of 20 °C, inlet pressure of 0.5 MPa, and flow velocity of 1.3 m/s. The heat load is applied on the center region of the mockup and the area is 300 mm x 101 mm. The heat flux is 0.5 MW/m^2 and the analysis result for the steady state is shown in Fig. 4. The maximum surface temperature is 174 °C for the N-01 mockup and 102 °C for the E-01, which shows the E-01 mockup has an enhanced cooling capability as expected.

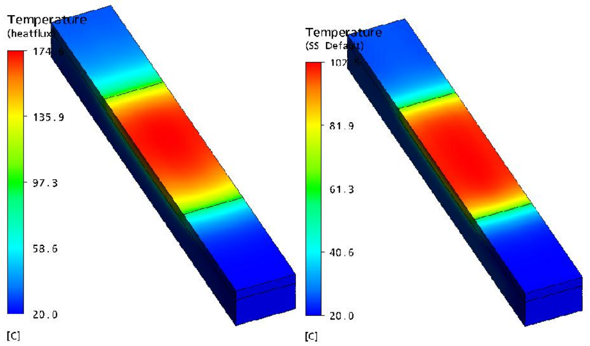

Fig. 4. The temperature profiles of two mockups with a heat flux of 0.5 MW/m^2 in a steady state.

The heat flux test was performed at the KoHLT-2 facility which was constructed in 2009 [5]. The KoHLT-2 consists of a graphite heating panel, a box-type test chamber, an electrical power supply, a water cooling system, an evacuation system, and some diagnostics as shown in Fig. 5. Two mockups can be installed in the chamber. The graphite heater is placed between two mockups, and the gap distance between the heater and the mockup is adjusted to 3 mm. The heater is connected to an electrical power supply of 200 V, 400 A. The effective heating area of the graphite heater is 300 mm x 101 mm. The heat flux is easily controlled by the power supply. We designed and fabricated the graphite heating panel to have an electrical resistance of 0.5 ohms during a high temperature operation.

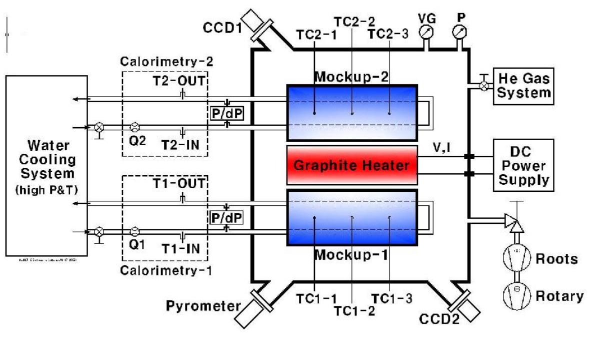

Fig. 5. Schematic diagram of the heat load test facility, KoHLT-2.

Figure 6 shows the constructed KoHLT-2 facility. The box-type large test chamber has a dimension of 1.2 m x 1.2 m x 2.4 m. The facility is equipped with two independent cooling loops for two mockups. Each loop consists of two thermocouples for measuring the inlet and the outlet temperature for the cooling water, and a flow meter, which gives an absorbed power through calorimetric computation,

$$P_{abs} = (T_{out} - T_{in})Q_w C_w, \qquad (1)$$

where Q_w is the mass flow rate and C_w is the specific heat of the cooling water. During the test, we measured the inlet/outlet temperatures and the flow rate of the cooling water to determine the absorbed heat flux on the mockups. We also measured the temperature of the mockups.

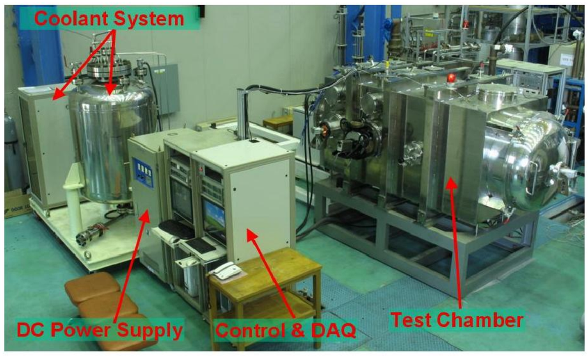

Fig. 6. KoHLT-2 heat load test facility constructed at KAERI.

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