Preliminary Operation of KoHLT-1 Heat Load Test Facility at KAERI

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1. Introduction

A heat load test is essential to develop the plasma facing components (PFCs) of a fusion device such as the first wall (FW), test blanket module (TBM), and divertor. In order to test a PFC at a high heat flux relevant to the ITER condition, we constructed a high heat load test facility called KoHLT-1 (Korea Heat Load Test facility), which is similar to BESTH [1] and EDA-BETA [2]. It has a graphite panel as a heat source. We have experimentally investigated the performance of the KoHLT-1 by using a Cu dummy mockup which has an identical surface area to the ITER (International Thermonuclear Experimental Reactor) first wall qualification mockup (FWQM).

2. Heat Load Test Facility

The KoHLT-1 consists of a graphite heating panel, two Cu dummy mockups which are enclosed in a box-type test chamber, an electrical power supply, a water cooling system, a evacuation system, and some diagnostics as shown in Fig. 1. The graphite heater is placed between two mockups as shown in Fig. 2, and the gap distance between the heater and the mockup is adjustable. The heater is connected to an electrical power supply of 100 V, 400 A. The effective heating area is 244 mm × 80 mm which is identical to the surface area of the ITER FWQM. 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 or 0.25 ohms.

The box-type test chamber has a dimension of 0.3 m × 0.3 m × 1.2 m and it has water cooling jackets on the front, rear, top, and bottom surfaces. The chamber has a large front door which has two viewing ports, six small ports on the top for the thermocouples, the vacuum gauge, and the electrical feedthroughs. It has a large port on the right side for four coolant channels. The facility is equipped with two independent cooling loops for two dummy mockups. Each loop consists of two thermocouples for measuring the inlet and the outlet temperature of the cooling water, and a flow meter, which gives an absorbed power through calorimetric computation, $P_{abs}=(T_{out}-T_{in}) \times Q_{water} \times C_p$, where Q_{water} is the mass flow rate and C_p is the specific heat of the cooling water. Three thermocouples are installed from the rear side of each mockup to measure the mockup temperature. A vacuum gauge is used to monitor the pressure variation during the heat load testing. Two dummy mockups are fabricated to calibrate the heat flux, and to check the reliability of the graphite heater system. It is made of Cu only, and has two cooling holes of 10 mmø.

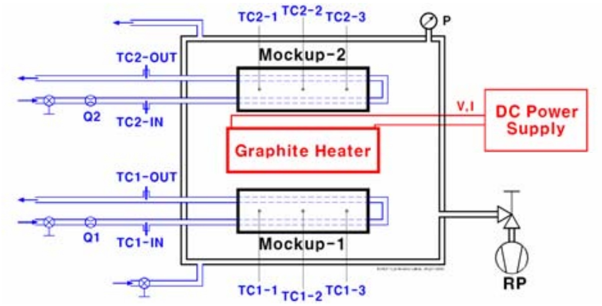

Fig. 1. Schematic diagram of the KoHLT-1 facility.

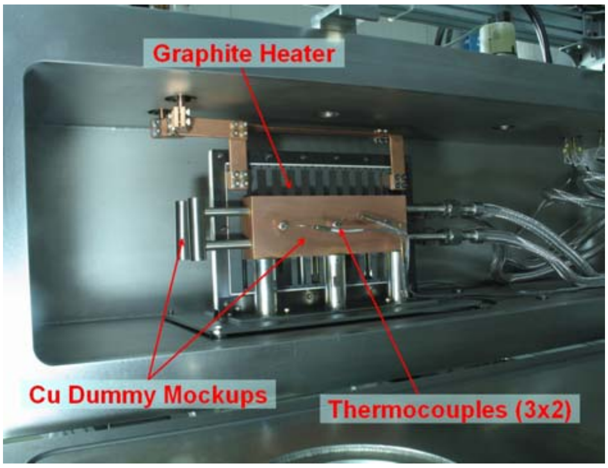

Fig. 2. Inside view of the KoHLT-1 facility.

3. Response of the Graphite Heater

The graphite heater provides the heat load by radiation. So the heating power is directly dependent on the temperature of the heating element. We calculated the radiation heat power from the graphite heater for various electrical currents. Figure 3 shows the response curves of the graphite heater with a resistance of 0.5 ohms for various currents. In this calculation, we assumed that the conduction heat loss is negligible. As shown in the figure, we need an electrical current of 280 A to obtain a heat flux higher than 0.7 MW/m^2, which is slightly higher than the heat load value for the testing of ITER FWQM of 0.625 MW/m^2. In that case, it take 22.4 sec to get the 90 % of the full heat load.

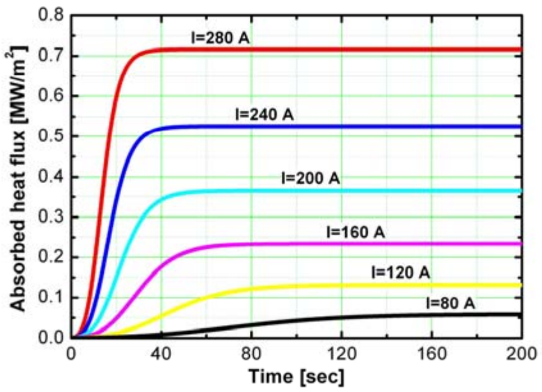

Fig. 3. Response curve of the graphite heater for various currents.

In the above discussion, we assumed that the resistance of the graphite is constant. However the resistance of the graphite heater is dependent on its temperature. So the resistance of the graphite heating panel is changed during the testing as shown in Fig. 4. The graphite has an unique characteristic for the temperature coefficient of the resistance. At an initial period of the testing, i.e., at low temperature, the resistance decreased and increased as the temperature increased. However the change of the resistance is not high.

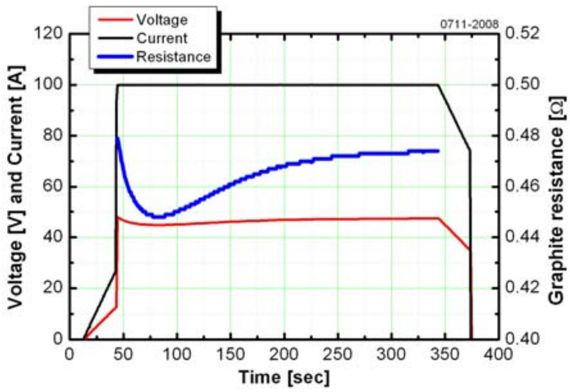

Fig. 4. Resistance variation during the heat load testing.

4. Heat Load Test of Dummy Mockup

We performed the thermal cycle test for the Cu dummy mockup at various testing conditions of the coolant flow rate, the heat flux, and the time durations of heating-up/cool-down. Figure 5 shows the graphite heater operating at 360 A. During the test, we measured the inlet/outlet temperatures and the flow rate of cooling water, the temperature of the mockups, and the pressure of the test chamber. Figure 5 shows a thermal cycle test result at a heat flux of 0.65 MW/m^2, and a flow rate of 5.0 kg/min. The temperature difference of the mockup during a test cycle was 118 ℃, which gives thermal stress. The difference of the coolant inlet and outlet temperatures was 36 ℃ which gives an absorbed power of 12.6 kW for the mockup-2. From this value, we can deduce the heat flux of 0.65 MW/m^2. The efficiency of the graphite heating panel was 77 % which is comparable to other facilities.

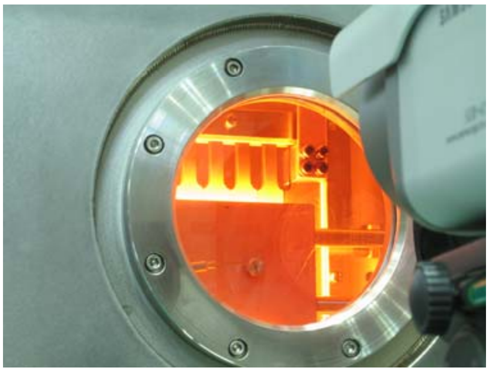

Fig. 5. Operating KoHLT-1.

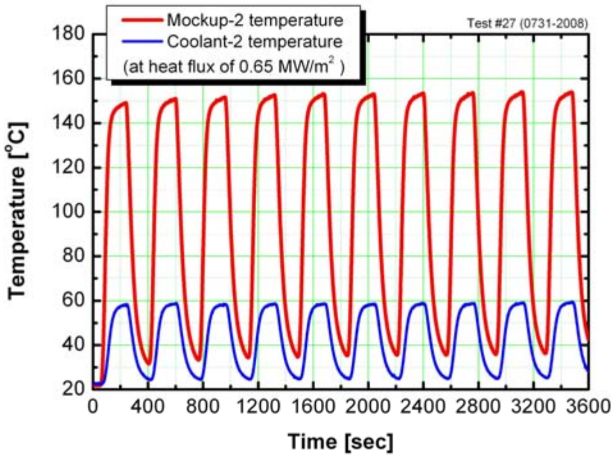

Fig. 6. Temperatures of the mockup and the cooling water during a thermal cycle test of the Cu dummy mockup at 0.65 MW/m^2.

5. Conclusions

A heat load test facility using a graphite heater was built at KAERI and its performances were studied. We carried out the heat load tests up to 20 cycles at 0.63 MW/m^2, 10 cycles at 0.65 MW/m^2 and 3 cycles at 0.73 MW/m^2 without any failure of the whole facility. It is confirmed that the KoHLT-1 facility can be used for thermal cycle tests of the ITER FWQM with a high reliability.

REFERENCES

[1] Ondrej Zlamal, Testing Status-EU: BESTH Device, ITER Blanket Progress Meeting, Prague, 03-06 June, 2008.

[2] Patrick Lorenzetto, Recent Results of Heat Flux Tests of FW Mock-ups, ITER FWQ-4 Meeting, Cadarache, 05-07 February 2007.