Evaluation and Simulations of KoHLT-EB for the Plasma Facing Components

Suk-Kwon Kim[a*], Hyung Gon Jin[a], Kyu In Shin[a], Bo Guen Choi[a], Eo Hwak Lee[a], Jae-Sung Yoon[a], Dong Won Lee[a], Seungyon Cho[b]
[a]*Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[b]*ITER Korea, National Fusion Research Institute, Daejeon, Republic of Korea*
[*]*Corresponding author: skkim93@kaeri.re.kr*

1. Introduction

The Korea Heat Load Test facility, KoHLT-EB (Electron Beam) has been operating for plasma facing components to develop fusion engineering in Korea. In order to perform a profile test, an assessment of the possibility of electron beam Gaussian power density profile and the results of the absorbed power for that profile before the test starts are need. To assess the possibility of a Gaussian profile, for the qualification test of Gaussian heat load profile, a small calorimeter was manufactured to simulate real heat profile in the neutral beam duct liner, and this calorimetry has two cooling channel with five thermocouples. Preliminary analyses with ANSYS-CFX using a 3D model were performed with the calorimeter model. The heating area was modeled to be 60 mm x 250 mm. A steady heat flux test was performed to measure the surface heat flux and surface temperature profile. With a thermo-hydraulic analysis and heat load test, the Gaussian heat profile will be confirmed for this calorimetry mockup.

2. Methods and Results

2.1 Heat load test facility

We have constructed an electron beam facility (KoHLT-EB; Korea Heat Load Test facility – Electron Beam) with a 800 kW electron gun for a high heat flux with a maximum beam power of 300 kW, and maximum accelerating voltage of 60 kV, as shown in Fig. 1. This electron beam facility is capable of continuous operation, and the pulsed operation of a cyclic heat load and controllable heat load, where the allowable target dimension is 70 cm × 50 cm in a vacuum chamber (about 140 cm diameter, 250 cm length). In addition, this facility needs a cooling system for a high-temperature target and decontamination system for beryllium filtration. This machine will be utilized for a cyclic heat flux test of the plasma facing components. Several facilities are now operating in the EU FZJ (JUDITH-2; 200 kW) [1], US SNL (EB-1200; 1,200 kW) [2], and the RF Efremov institute (TSEFEY; 200 kW, IDTF; 800 kW) [3]. Each facility is dedicated to unique targets of their own purpose in each country. The KoHLT-1 (Korea Heat Load Test facility) and KoHLT-2 test facilities using a graphite heater were constructed to perform a high heat flux test of small mockups for the ITER first wall and plasma facing components [4-6].

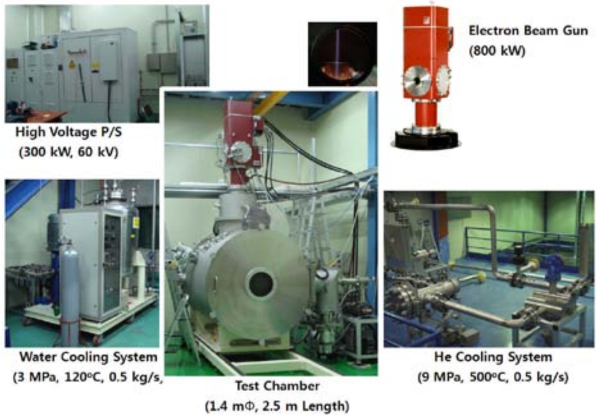

Fig. 1. High heat flux test facility by using an electron gun and helium cooling system.

2.2 Simulation and evaluation test

In order to perform the profile test, an assessment of the possibility of electron beam Gaussian power density profile and the results of the absorbed power for that profile before the test starts are need. To assess the possibility of a Gaussian profile, for the qualification test of the Gaussian heat load profile, a small calorimeter was manufactured to simulate real heat, and this calorimeter has two cooling channel with five thermocouples, as shown in Fig. 2. In addition, Fig. 3 illustrates the electron beam deposition in the target, which was simulated in the power control system.

For an evaluation of the beam quality in the target area, the dummy mockup was fabricated and tested, which have a hypervapotron cooling channel. Fig. 4 shows the hypervapotron dummy mockup, which was installed in the test facility.

Fig. 2. Test mockup for the thermo-hydraulic calorimetry.

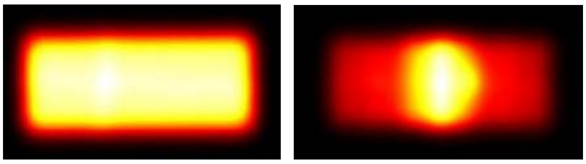

Fig. 3. Simulated beam deposition in the test mockup in the power supply monitoring system. (Left: flat beam profile, right: Gaussian peak profile)

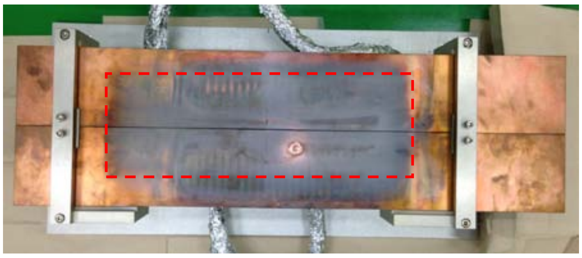

Fig. 4 Dummy test mockup with the hypervapotron cooling channel (Red rectangular: beam deposition)

This hypervapotron cooling device was used to check the performance of the heat load and we have performed a non-destructive test for a small-scale mockup using an ultra-sonic test (UT) in this electron beam facility. The methods used to measure the temperature of this system were selected using the calorimeter for the coolant temperature and heat flux, the thermocouples for the bulk temperature of the test mockups and IR camera, and pyrometers for the mockup surface temperature under normal directions.

2.3 Test Results

Fig. 5 shows the target surface temperature of the hypervapotron dummy mock-up. The peak temperature of uniform heat flux was acquired from the center thermocouples by 67.09 °C and 65.43 °C for a normal and hypervapotron mock-up, respectively. In addition, 83.31 °C and 76.31 °C were acquired from the Gaussian profile heat flux at the center thermocouples. The test results show that the calculated heat flux from the calorimeter and the temperature from the thermocouples have similar behavior.

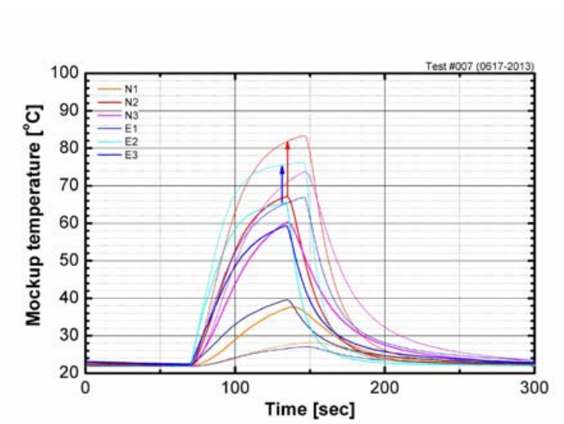

Fig. 5. Surface temperature of hypervapotron dummy mockup

In Fig. 5, N1, N2, and N3 are the upper-half part of the dummy mockup, which has a flat cooling channel, and E1, E2, and E3 are the lower-half part which has a hypervapotron cooling channel. The temperatures of the Gaussian profile at the center positions (N2 and E2) were shifted to a higher level than the flat profile beam deposition.

3. Conclusions

The calorimetry mockup and hypervapotron dummy mockup were fabricated to evaluate the performance of the high heat flux test facility. Validation analyses were simulated using the thermo-hydraulic code to confirm the heat load condition. Using an electron beam system, a Korean heat load test facility was constructed to evaluate the performance of the plasma facing components. A cyclic heat flux test was performed to measure the surface heat flux, surface temperature profile, and cooling with a thermo-hydraulic analysis and heat load test. The Korean heat load test facility will be used to qualify the specifications of various plasma facing components in fusion devices.

REFERENCES

[1] Patrick Majerus et al., “The new electron beam test facility JUDITH II for high heat flux experiments on plasma facing components,” Fusion Eng. Des., 75–79, 365 (2005).
[2] J.M. McDonald et al., “The Sandia plasma materials test facility in 2007,” Fusion Eng. Des., 83, 1087 (2008).
[3] G.M. Kalinin et al., “Development of fabrication technology and investigation of properties of steel-to-bronze joints suggested for ITER HHF components,” J. Nucl. Mater., 386–388, 927 (2009).
[4] Young-Dug Bae et al., “Development of a High Heat Flux Test Facility for Plasma Facing Components,” Fusion Sci. Technol., 56, 91 (2009).
[5] Young-Dug Bae et al., “Heat flux tests of the ITER first Wall qualification mockups at KoHLT-1,” Fusion Eng. Des., 86, 412 (2011).
[6] Suk-Kwon Kim et al., “Overview of Korea heat load test facilities for plasma facing components,” Fusion Eng. Des., 85, 1834 (2010).