Heat Load Test Facility Using Electron Beam System for the Plasma Facing Components

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1. Introduction

A Korean high heat flux test facility for the semi-prototype (SP) qualification of an ITER first wall (FW) will be constructed to evaluate the fabrication technologies required for the ITER FW, and the acceptance of these developed technologies will be established for the ITER FW manufacturing procedure. Korea participated in this qualification program, and is responsible for suitable arrangements for the heat flux test of our fabricated SPs. Qualification testing can be started provided that adequate quality and control measures are implemented and validated by the ITER Organization (IO). The controlling measures required for all heat flux tests shall be concrete and demonstrate the satisfaction of the IO test programs. Each country shall provide a test plan covering the quality and controlling measures in the high heat flux test facility to be implemented throughout the test program. Korean high heat flux testing for these ITER plasma facing materials will be performed by using a 60 kV electron beam and a power supply system of 300 kW, where the allowable target dimension is 70 cm × 50 cm in a vacuum chamber. In addition, this facility needs a cooling system for a high-temperature target and decontamination system for beryllium filtration.

2. Methods and Results

ITER FW, in addition to plasma facing components (PFC), plays a great role in a fusion reactor, and very extensive researches have been performed to develop these PFC materials. We have fabricated and tested the first wall mockups to qualify the manufacturing process, which makes the bonding between beryllium, as a PFC, and heat sinkers, such as Cu and stainless steel (SS). These types of mockups were tested using the international round robin test [1] in several electron beam facilities of the US [2], EU [3], Russia [4], etc. In 2009, through the contracts between the ITER Organization and all parties, each party has fabricated the first wall qualification mockups for the heat flux test in the US and EU. The US test facility is an EB-1200 of the Sandia National Laboratory [2], and the EU facility is JUDITH-2 [3] in the Forschungszentrum Juelich of Germany.

For preparing the qualification program and more, obtaining the procurement eligibility and fabrication methods for the FW has been developed in Korea [5,6]; the various joining methods were investigated for an improvement of the bonding performances between Be tile and Cu alloy, and Cu alloy and the SS block, respectively and, finally, a Hot Isostatic Pressing (HIP) bonding method was chosen considering the complex geometry of the FW. The various samples such as Be/Cu and Be/Cu/SS blocks with coating layers in Be tile were fabricated to find the optimized bonding conditions. Various mockups with different dimensions and coating layers were fabricated to find an optimized bonding condition and canning methods for the HIP. Also, cyclic HHF tests were performed for the validation of the joining integrities of the mockups using various test facilities [7-12]: Be/Cu mockup tests in the Russian TSEFEY facility [4], and Be/Cu/SS mockup tests in JUDITH-2 [3].

2.1 Electron Beam System

The ITER FW includes beryllium armour tiles joined to a CuCrZr heat sink with stainless steel cooling tubes. The first wall panels are one of the critical components in the ITER machine with a surface heat flux of 4.7 MW/m^2 or above. Thus, a qualification program needs to be performed with the goal to qualify the joining technologies required for the ITER First Wall. Based on the results of these tests, the acceptance of the developed joining technologies will be established. The results of this qualification test will affect the final selection of the manufacturers for the ITER First Wall.

We will construct an electron beam facility, as shown in figure 1, with an 800 kW electron gun power (from Von Ardenne GmbH, Germany) for a high heat flux with maximum electron beam power of 300 kW power,

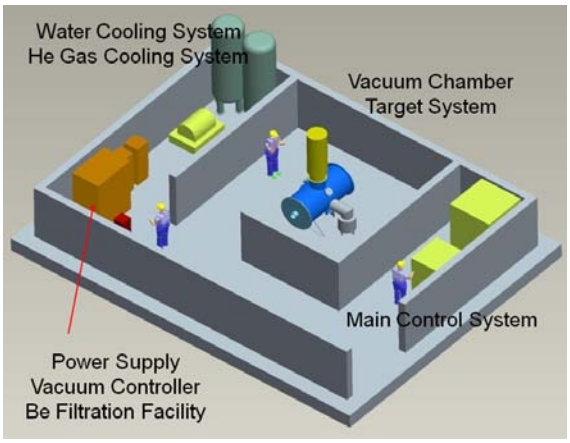

Fig. 1. Conceptual design of Korean electron beam facility for high heat flux tests.

maximum accelerating voltage of 60 kV, and maximum target size of 700 × 500 mm^2 (maximum heat load for a scanning area of 300 × 20 mm^2 is about 4.7 MW/m^2).

We have selected the power supply and electron gun according to the maker's specifications and the extension of power supply up to 800 kW will be scheduled in the next upgrade period of our institute. This machine will be utilized for a cyclic heat flux test of plasma facing components.

2.2 Construction

Several facilities are now operating in EU FZJ (JUDITH-2 200 kW) [3], US SNL (EB1200) [2], and RF Efremov institute (IDTF 800 kW) [4]. We will perform a non-destructive test for a small-scale mockup with this electron beam facility. Also, figure 2 shows the high heat flux test facility for plasma facing components using an electron gun and helium cooling system. The methods to measure the temperature of this system will be selected with 1) the calorimetry for the coolant temperature and heat flux, 2) the thermocouples for the bulk temperature of the test mockups and 3) IR camera and pyrometers for the mockup surface temperature to the normal directions.

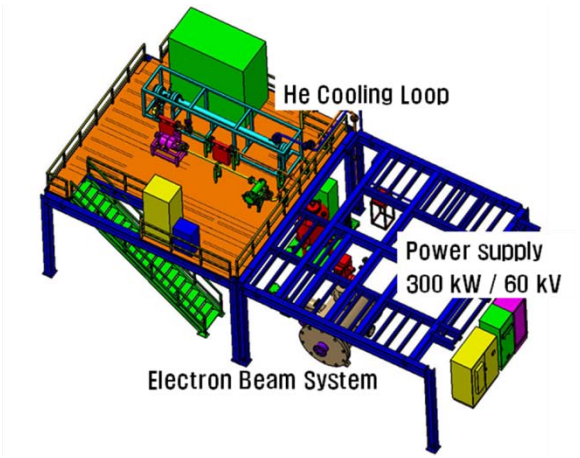

Fig. 2. High heat flux test facility for plasma facing components by using an electron gun and helium cooling system.

3. Conclusions

A Korean high heat flux test facility for the semi-prototype qualification of an ITER first wall will be constructed to evaluate the fabrication technologies required for the ITER FW. These Korean high heat flux test facility for the plasma facing materials will be performed using an electron beam, a power supply system, a vacuum test chamber, and a beryllium filtration system. The ITER first wall qualification test at up to a 4.7 MW/m^2 high heat flux will be performed using this electron beam facility in Korea. Also, this system will be used to test other PFCs for ITER and materials for tokamak reactors.

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