High Heat Flux Test for the Semi-Prototype Qualification of ITER First Wall

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1. Introduction

Korean high heat flux test facility for the semi-prototype (SP) qualification of 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 participate in this qualification program, and responsible for a suitable arrangements for the heat flux test of our fabricated SPs. Qualification test can start provided that adequate quality and control measures are implemented and validated by ITER Organization (IO). The controlling measures required for all heat flux tests shall be concrete and demonstrated to 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.

2. Methods and Results

2.1 Fabrications

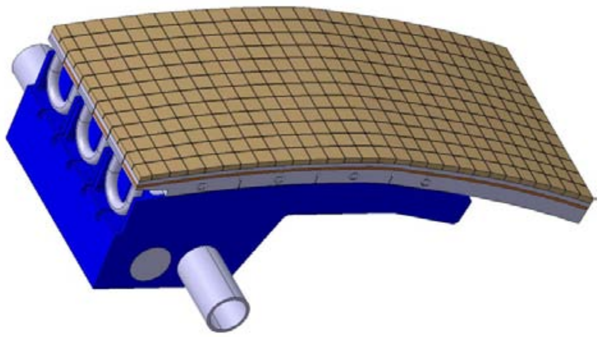

Fig. 1. 3D scheme of the ITER first wall semi-prototype.

The 3D scheme for the ITER first wall (FW) semi-prototype (SP) is in the Fig. 1. [1] The semi-prototype is a part of main first wall frame which has three double-fingered panels (Fig. 2). These single fingers are fabricated to qualify our HIP (Hot Isostatic Pressing) technology and fabrication methodology. The design shall be used to withstand the high heat load up to 4.7 MW/m^2. This goal shall be to develop and optimize the design using joining processes developed in the FW qualification program where possible and utilizing a heat sink with enhanced heat removal capability. The design was based on the implementation of a heat sink using hypervapotron technology.

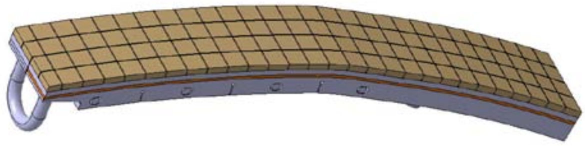

Fig. 2. Single finger of ITER FW SP for high heat flux test.

For the CuCrZr and stainless steel, the canned materials were placed into the HIP furnace. HIP was conducted at 1,050 °C and 100 MPa for 2 hours with the heating rate of 5 °C/min and the furnace cooling [2]. During the heating process, the temperature was held at 900 °C for 210 min for pressure control and the homogenizing of the materials. In the case of Be to CuCrZr HIPping, the canned materials were placed into a HIP furnace. HIP was conducted at 580 °C and 100 MPa for 2 hours with the heating rate of 4 °C/min and the furnace cooling. The canning plates were removed by electro-discharge machining.

2.2 High Heat Flux Test Facility

For the optimization of the test conditions, the preliminary thermal and mechanical analyses were performed by using CFX thermo-hydraulic simulation code. These results are to simulate the test conditions and determine the number of cycles for fatigue lifetime of the mockups [3-6]. The coolant data for these simulations are such that inlet temperature is 70 °C, inlet pressure 2 MPa, and coolant speed 2 m/s.

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. The heat flux shall be generated by an electron beam test facility, which shall have the features of Table I.

Table I. Specifications for high heat flux test facility by using electron beam system.

	Conditions
Electron beam power	Max. 200 kW
Acceleration voltage	Max. 220 kV
Water cooling system	Inlet pressure : 0 ~ 45 bar Inlet temperature : 0 ~ 150 °C Flow rate : 0 ~ 30 m^3/h

Korean high heat flux test for these ITER plasma facing materials by using 60 kV electron beam facility

(Von Ardenne GmbH, model EH800V), will be constructed with the power supply system of 300 kW (model HS300/60MF, maximum heat load up to 10 GW/m^2), capable of continuous operation, pulsed operation of cyclic heat load, and controllable heat load, and the allowable target dimension is 70 cm x 50 cm in the vacuum chamber (about 120 cm diameter, 200 cm length).

2.3 Qualification Tests

Table II shows the test condition in the high heat flux test facility for semi-prototype qualification.

Table II. Condition for high heat flux test of ITER FW SP.

Step	Heat Flux and cycles	Cycle duration	Area
Initial Thermal mapping Cycle	$0.5MW/m^2$	Sufficient for Steady State	80% of SP Beryllium surface
Step 1	7500 cycles 4.7 MW/m^2	30 s/ 30 s on/off	50% of SP Beryllium surface
Intermediate Thermal mapping	$0.5MW/m^2$	Sufficient for Steady State	80% of SP Beryllium surface
Step 2	1500 cycles 5.9 MW/m^2	30 s/ 30 s on/off	>5% of SP Beryllium surface
Thermal mapping	$0.5MW/m^2$	Sufficient for Steady State	80% of SP Beryllium surface

These test conditions details the requirements of the qualification performance for Enhanced Heat Flux (EHF) FW panels comprising heat flux technologies up to a design value of 4.7 MW/m^2. This experiment must be successfully completed prior to issuing of fabrication methodology for ITER FW semi-prototype.

3. Conclusions

The ITER first wall semi-prototype fingers to establish the manufacturing capability of Korea were fabricated in the shape of 700 mm x 100 mm with hypervapotron heat sink. Each finger must endure the 7,500 normal heat cycles in the high heat flux of 4.7 MW/m^2 by using electron beam test facility. These tests have been performed for the purpose of qualifying the joining technologies required for the ITER first wall and semi-prototype.

REFERENCES

[1] Specification for the Enhanced Heat Flux First Wall Panel SP DA Qualification Program, ITER_D_2M5783 v1.7, March 2011.
[2] Young-Dug Bae, et al., “Development of a High Heat Flux Test Facility for Plasma Facing Components,” Fusion Sci. Technol. 56, 91 (2009).
[3] Jeong-Yong Park, et al., “Fabrication of Be/CuCrZr/SS mock-ups for ITER first wall,” Fusion Eng. Des. 84, 1568 (2009).
[4] Dong Won Lee, et al., “High heat flux test with HIP-bonded Cu/SS mock-ups for the ITER first wall,” Fusion Eng. Des. 83, 1038 (2009).
[5] Dong Won Lee, et al., “High heat flux test with HIP bonded Be/Cu/SS mock-ups for the ITER first wall,” Fusion Eng. Des. 84, 1160 (2009).
[6] Dong Won Lee, et al., “High Heat Flux Test with HIP Bonded 50x50 Be/Cu Mock-Ups for the ITER First Wall,” Fusion Sci. Technol. 56, 48 (2009).