

§59. Evaluation for High Z Divertor Plate Module of LHD

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LID divertor plate of LHD will be subjected to high heat flux of about 10 MW/m^2 and armor brazed with OFHC is going to be used as LID divertor plate. In this study, (1) in order to examine material damage and thermal response of carbon fiber composite(CFC) as armor materials, thermal performance tests and thermal fatigue lifetime tests using electron beam facilities were carried out. Calculation of thermal performance was also carried out. (2) Thick tungsten coatings on carbon carbon composite and other carbon materials was also newly successfully demonstrated. High heat flux experiments were performed on the coated tiles in order to prove the suitability and load limit of such coating materials.

(1) CFC armor brazed with OFHC

Three tiles of CFCs were jointed by silver brazing on the OFHC surface with a cooling tube by Mitsubishi Heavy Industry Corporation. CX-2002U(Toyo Tanso Co., LTD.) and MFC-1(Mitsubishi Heavy Industry Co.) were used as CFCs. The Center tile of three tiles was irradiated by electron beam and temperature of center tile was measured with pyrometers and temperatures of upper side and down side of interface of brazing area were also measured with thermocouples. Heat flux tests were carried out using ACT of National Institute for Fusion Science and EBTS of Sandia National Laboratories. Thermal performance experiments were carried out under condition that the water flow velocity, pressure and temperature were 1.6 - 10 m/s, 1.0 - 4.0 MPa and 20, 150 °C respectively at EBTS. Heat load was 1 to 14 MW/m^2 . After the irradiation, modification of

surface of CFC and interface of CFC and OFHC were observed with a scanning electron microscope(SEM). Ultrasonic testing were also performed in order to examine adhesion property of the CFC and OFHC after the irradiation.

The MFC-1 Mock-up showed good heat removal performance. This is expected to be due to high thermal conductivity. Thermal fatigue test showed that temperature increase due to degradation was not observed until the number of cyclic of 1000, but slight cracks between CFC and brazed materials were observed. This results correspond to formation of hot brightness area during the electron beam irradiation. Calculation for thermal response using a finite element analysis code showed relatively good agreements with the experimental results under condition that it is expected film boiling does not occurred.

(2) Thick tungsten coatings

Tiles, 20mm x 20mm x 10mm, were coated by vacuum plasma spraying technique(VPS). The substrate materials were carbon carbon composite CX-2002U, isotropic fine graphite IG-430U. The CX-2002U and IG-430U received a diffusion barrier layer prior to the VPS coating in order to inhibit uncontrolled brittle carbide formation. Thickness of the tungsten coating layer were 0.5 mm and 1.0 mm.

The specimens were exposed to electron beam with a duration of 10 sec. During the irradiation, the surface temperature was measured by a two color pyrometer and desorbed gases from specimen were monitored by a quadrupole mass spectrometer (QMS). Modification of surface morphology by the heat load was observed by a scanning electron microscope(SEM).

SEM observation showed that spherical particles were partially melted and joined each other and pores were formed in the coating. Thermal stress due to temperature increase by heat load may be released by pores. The electron beam irradiation experiments showed that there was little difference about temperature increases among CX-2002U and the coated materials below surface temperature of 2200 °C. This results indicated adhesion property between the substrate and coatings were good under high heat flux.