§40. R&D of Mechanically Jointed Divertor Plate for LHD

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Mechanical joint type of divertor plates (more than 1700) are attached inside the vacuum vessel of LHD to protect the vacuum vessel wall. In order to apply to divertor plates of LHD, R&D of mechanically jointed divertor piece(MJDP) have been carried out using a high heat flux test stand ACT[1] with a 100kW electron beam source and thermal desorption spectrometer (TDS)[2] with a 1400°C infrared furnace. The MJDP consists of an iso-graphite armor tile, two backing plates(upper and lower), stainless steel cooling pipe, and carbon sheets. The carbon sheet is used to improve thermal contact between the tile and plate and between the cooling pipe and plate. These components are fixed with several stainless steel bolts. ACT and TDS are used for the evaluation of thermal properties of the MJDP under high heat flux tests and outgassing of the graphite bond to fix the carbon sheet on the upper backing plate, respectively.

First, the effect of the backing plate material on the thermal properties of MJDP is described. With increase of heat flux irradiated on the MJDP, the temperature of the copper backing plate rises gradually. The heat transfer between the cooling pipe and copper backing plate sharply decreases when the temperature exceeds about 250 °C, and the thermal properties of MJDP become worse due to the thermal deformation of the copper backing plate. Oxygen free copper(OFC) is generally used as the backing plate material. Several heat flux tests of MJDP indicated that the deformation is caused by reduction tensile strength of OFC in higher temperature than 250 °C and a large thermal expansion coefficient. In order to avoid the deformation of the backing plate, beryllium copper(BC), chromium copper(CC), dispersion strengthen copper(DSC), and iso-graphite(IG) were tested as the backing plate instead of OFC because DSC, BC, CC, and IG keep a high tensile strength even in higher temperature over 250 °C, and moreover IG has a low expansion coefficient .

The heat flux tests carried out under up to 1.4MW/m^2 for steady operation showed that MJDP with DSC or graphite backing plate has better thermal properties than those with other materials as expected. The test result also suggests that the effect of thickness of carbon sheet between the cooling pipe and copper backing plate on the heat transfer at the mechanical interface is large. With a thinner carbon sheet than 0.2mm, the thermal properties of MJDP become worse even if under lower heat fluxes than 0.75 MW/m^2. This tendency for the thickness differs from another test result[1] for a compact mechanically jointed piece. Considering the results and cost performance, use of an IG backing plate and thicker carbon sheet is recommend for MJDP.

Second, new type of MJDP developed and tested recently is described. As shown in Fig.1, the graphite armor tile of the MJDP is combined with a backing plate to reduce number of the mechanical interface, which largely disturbs heat transfer in MJDP. Moreover, a super graphite sheet with a better thermal conductivity and higher expanding strength than that of carbon sheet used in the old separate type of MJDP. As a result, this new MJDP has many merits, light weight(about 40% reduction), simple structure, low cost, and excellent thermal properties in comparison with the old separate type of MJDP. The thermal properties of the new MJDP have been evaluated under steady heat fluxes up to 1.8 MW/m^2 as parameters of thickness of graphite sheet and cooling pipe. However, the evaluations for strength and outgassing of the combination of new MJDP must be well performed because of graphite block.

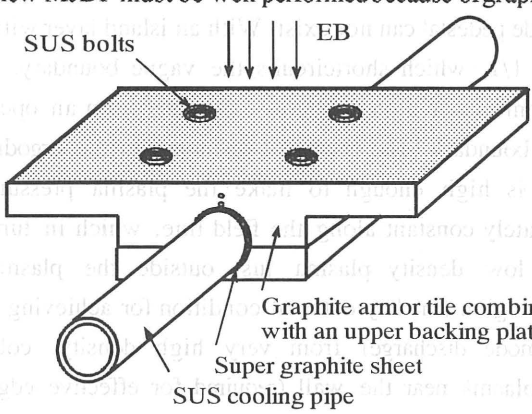

Fig.1 New type of MJDP using a graphite armor tile combined with a graphite backing plate.

Third, the outgassing of graphite bond to fix the carbon sheet on the backing plate is described. The graphite bond of 15g in total is used when mechanically jointed divertor plates are installed inside the vacuum vessel of LHD. To reduce the outgassing from the bond during plasma operation in a vacuum, several conditionings of the bond have been evaluated. Change in weight of the bond in air and the outgassing in vacuum have been measured using a minute balance and TDS, respectively. As a result, a natural drying method without degassing by heating is recommended as a conditioning method of graphite bond because of simplicity. Natural dryings for 3 days in air and for 1.5 days in vacuum reduce the total outgassing of the bond by about 60% and 36%, respectively. Only about 4% of outgassing remains after the dryings. Moreover, no harmful gas components like as halogen was found in the desorbed gas. Almost all of the outgassing is due to water vapor which doesn't severely disturb the plasma experiment.

References

1) Kubota,Y., Noda,N., et al.: NIFS-Memo-16(1995).

2) Kubota,Y. and Miyahara, A.: IPPJ-DT-139(1988).