§1. R&D of Surface-Boltless Mechanically Attached Divertor Plate for LHD

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A surface-boltless mechanically attached divertor plate (SBLDP) has been developed and applied to LHD in the seventh campaign as a standing type instead of normal mechanically attached divertor plates (NMADP). Comparison of the structure and thermal performance between the two types of divertor plates has been done. About 1,700 NMADPs have been installed in LHD since the third campaign, each of which consists of a graphite armor tile, a copper heat sink, a stainless steel(SS) back plate, and normal graphite sheets to improve thermal transfer, which are tightly fixed with eight SS bolts sandwiching a SS cooling pipe. They worked without any trouble till the fifth campaign. However, during long pulse plasma experiment in the sixth campaign by ICRH, a remarkable temperature increase and hot spots were observed on the graphite armor tile of the standing type of NMADP. An increase in the temperature of divertor plate leads to a great deal of gas desorption. Moreover, partially melted tracks caused by a dense plasma irradiation were observed on the SS bolt heads used to fix the armor tile, which may be an origin of high Z impurity in core plasma. To achieve successfully long pulse plasma experiment as an important mission of LHD, the large improvement of thermal performance of helical divertor plates and boltless structure on armor tile surface are strongly required. Therefore, SBLDP without any bolt on the tile surface and a copper heat sink which leads to the poor thermal performance has been developed and evaluated using a test facility ACT with a 100kW electron gun. The cross-sectional view of SBLDP is shown in Fig.1. The divertor plate consists of a couple of graphite armor tiles and super graphite sheet, which are tightly fixed horizontally with two TZM(or SS) bolts sandwiching the cooling pipe.

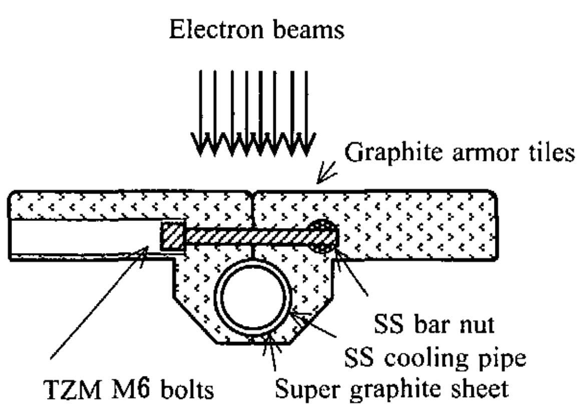

Fig.1 Cross-sectional view of surface boltless mechanically attached divertor plate for LHD.

The armor tile material is iso-graphite(IG-430U) with a thermal conductivity of 139W/mK similar to that of NMADP. However, the super graphite sheet(PGS-100) has very excellent thermal and mechanical properties different from the normal graphite sheet(PF-20UHP) used in the NMADP. The disassembled structure of SBLDP is compared with that of NMADP in Fig.2. The simple structure of SBLDP allows to reduce the number of bolts used for fix to 1/4, the total weight by 40%, and the setting time to half compared to the previous one.

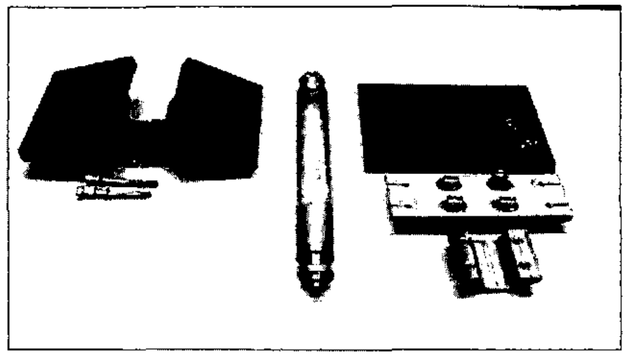

Fig.2 A comparison of the structures between two types. The left is SBLDP and the right is NMADP.

The thermal performance and outgassing of the SBLDP have been evaluated comparing with those of NMADP using a test facility ACT. High heat flux tests up to 1.2 MW/m^2 for steady state operation have been carried out, and the relationship between the temperature and heat flux is shown in Fig.3. The figure indicates that the allowable heat flux of SBLDP exceeds 1.0 MW/m^2 although that of NMADP is limited to the low value, about 0.3 MW/m^2. By changing SS bolts(Red line) to TZM bolts(Black line), which are used to fix the armor tiles, the thermal performance is more improved. The gas amount desorbed from SBLDP during high heat flux tests from 0.1 to 0.5 MW/m^2 is much reduced, less than one-third of that of NMADP.

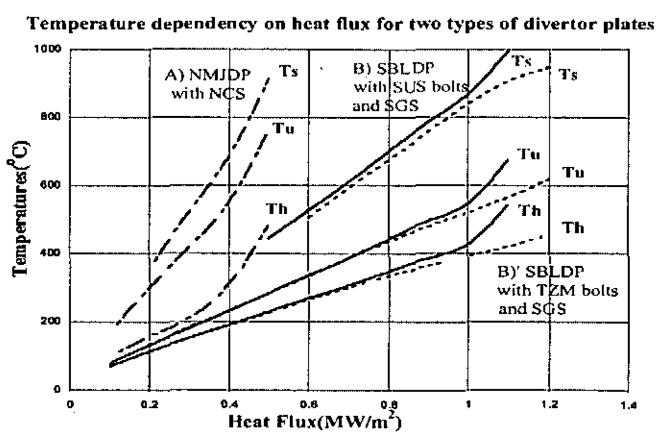

Fig.3 Relationship between the applied heat flux and measured temperatures. Ts,Tu, and Th are temperatures at the tile surface, tile bottom, and heat sink, respectively.