§6. Optimization of the Design of a Vacuum Pumping System for the Closed Helical Divertor in LHD

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For effective particle control in the LHD plasma periphery, test modules of closed helical divertor (CHD) components were installed in the inboard side of the torus in the last experimental campaign (14th cycle). The CHD consists of slanted divertor plates, a dome structure and target plates installed along the space between two helical coil cans. Three-dimensional neutral particle transport simulation predicts that the neutral particle density behind the dome is enhanced by more than one-order of magnitude in the CHD configuration compared to that in the open divertor configuration for R_{ax}=3.60m. Measurements with fast ion gauges installed in the in board side in the CHD (9-I) and in the open divertor region (6-I) clearly showed that enhancement of the neutral particle density in the CHD region as predicted by the simulation.

One of the next important issues of the CHD is efficient neutral particle pumping from the inboard side by installing a vacuum pumping system behind the dome. A cryogenic adsorption panel cooled by liquid or gas He covered with LN_2 cooled chevrons and water cooled (WC) blinds was proposed as a promising candidate. This is because a preliminary analysis using a neutral particle transport simulation code (EIRENE) showed that the pumping efficiency for a pumping system with WC blinds is higher than that with WC chevrons by ~50%.

One of the concerns for the pumping system is the heat load on the liquid/gas He cooled panel (LHe cooled panel), because the pumping system faces to the heat source (divertor plates) at a short distance (~0.1m) on the equatorial plane in the inboard side of the torus. There are two physical mechanisms of heat transfer from the divertor plate to the LHe cooled panel. One is radiation by heated divertor plates, another one is thermal conduction due to neutral particles. Heat loads by radiation on the components of the pumping system with WC blinds was investigated using a finite element method based software for multi-physics analysis (ANSYS), showing that the total heat load on the LHe cooled panel is ~30W for the full torus geometry.

Heat loads on the components of the pumping system by thermal conduction due to neutral particles are investigated by the neutral particle transport simulation code using a two-dimensional model of the pumping system. Figure 1(a) shows the heat loads on the WC blinds, the LN_2 cooled chevrons and the LHe panel. In this calculation, plasma parameters on the divertor leg are set to be as follows: n_e^{div}=1.0×10^{13}cm^{-3}, T_e^{div}=30eV. The total plasma current onto the divertor plate is 1A(H^+), and the temperature of the surface of the divertor plates is 1,073K, and no particle pumping effect on the divertor plates and on the vacuum vessel is included.

Buffer plates (carbon) were proposed for the reduction of the heat load on the LHe cooled panel due to thermal conduction. Many grooves (2mm in width, 5mm in depth and 2mm in interval) on the surface of the buffer plate induce multiplex reflection of the neutral particles to diminish the kinetic energy of the particles reflected and released from the divertor plates.

Figure 1(b) illustrates the cross section of the two-dimensional model of the pumping system (a half part) with the buffer plates installed on the surface of the vacuum vessel in the inboard side as one of the WC components. Figure 1(a) shows that the heat load on the WC components rises by installation of the buffer plates and it contributes to reduction of the heat load on the LHe cooled panel by about 25%. For further reduction of the heat load, the buffer plates are additionally installed in the upper part of the component of the WC blinds (Figure 1(c)) and also on the LN_2 cooled chevrons (Figure 1(d)). Figure 1(a) indicates that the additional buffer plates are effective to decrease the heat load on the LHe cooled panel, showing that the heat load is finally reduced to about 15% by installation of the three buffer plates.

The maximum requirement of the neutral particle pumping rate for the pumping system is about 10^4A in continuous fuelling pellet discharges. The estimated heat load for the full torus geometry is about 113W in the case with the all additional buffer plates. It means that this estimation is much higher than that due to radiation. The calculation also demonstrates that the all buffer plates reduce the pumping rate of neutral particles on the LHe cooled panel by about 20% as shown as crosses in Figure 1(a). It indicates that the significant reduction of the heat load is achieved by installation of the buffer plates without serious reduction of the pumping rate.

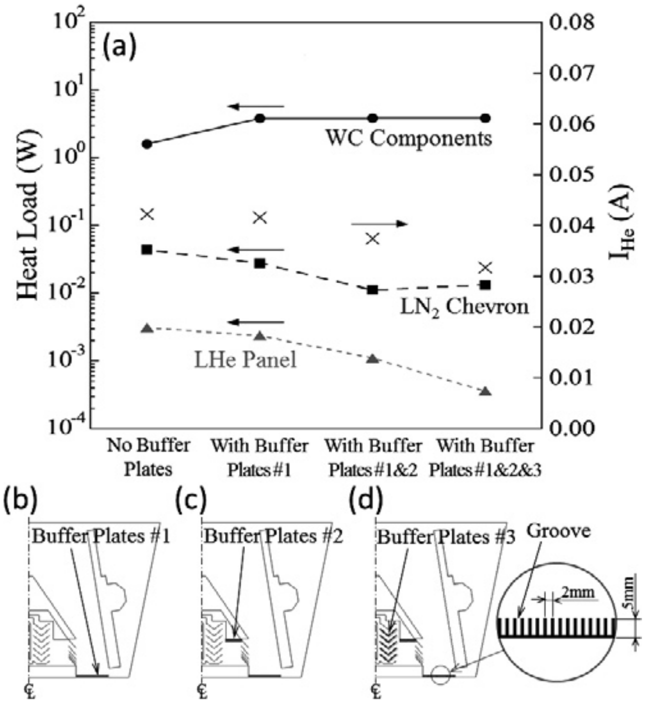

Fig. 1 Heat load on the three components of the pumping system for the CHD (a), cross section of the two-dimensional model of the pumping system with buffer plates on the surface of the vacuum vessel in the inboard side (b), with additional buffer plates in the upper part of the component of the WC blinds (c), and on the LN_2 cooled chevrons (d).