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

Shoji, M., Masuzaki, S., Sakamoto, R., Takeiri, Y.

The Closed Helical Divertor (CHD) was constructed for peripheral plasma density control and efficient particle pumping. The CHD consists of three components: slanted divertor plates, a dome structure, and target plates. Enhancement of the neutral particle density behind the dome structure by more than one order of magnitude is expected for the CHD compared with that for the present open divertor configuration. For achieving the above purposes, installation of a vacuum pumping system behind the dome structure is now planned.

Detailed analysis of the behavior of neutral particles (H, H_2) in the CHD region is essentil for optimizing the structure of the pumping system. For this reason, a fully three-dimensional simulation code (EIRENE) was applied. Figure 1 shows three-dimensional models for simulating neutral particle transport in the CHD region. The components of the CHD and the vacuum pumping system are constructed two-dimensionally in this model in which the configuration of these components is arranged as that in the most inboard side of the torus for estimating the highest heat load onto the components. Two types of the pumping system were investigated, which are composed of a water cooled chevron/blind (Al), a liquid nitrogen (LN_2) cooled chevron (Al), and a liquid helium (LHe) cooled panel (Fe). The left end in the model is treated as a mirror surface (symmetrical with respect to the X-Y plane), and the top surface is regarded as an exit. The right and bottom surfaces are vacuum vessels (Fe). The material of the divertor plate and dome is treated as carbon. Plasma parameters on the divertor leg are as follows: n_e^{div}=1.0×10^{13}cm^{-3}, T_e^{div}=30eV. The divertor plasma exists over the dome structure, and the plasma is wetted on the lower half of the divertor plate. The total plasma current onto the divertor plate is 1A(H^+). Colored lines in the models represent the trajectories of the neutral particles.

The neutral particle reflection on the components of the CHD and the pumping system is treated as follows:

1. Hydrogen ions are neutralized on the divertor plate on which the reflected atoms (H) and thermally desorbed molecules (H_2) are released. The ratio of the number of the atoms and the molecules is determined by the TRIM code. Particle absorption is NOT included.
2. Some neutral hydrogen atoms colliding with the components are reflected. The energy of the reflected atoms is determined by the TRIM code. The other atoms are desorbed as molecules which energy corresponds to the temperature of the components.
3. The energy of neutral hydrogen molecules desorbed from the components is determined by a parameter R_{ref}. When molecules collide with the components, a uniform random number ρ (0<ρ<1) is generated. For ρ<R_{ref}, the energy (velocity) of the reflected molecules keep the initial incident energy. For ρ>R_{ref}, the energy of the desorbed molecules is changed to that corresponding to the temperature of the components.
4. Neutral particles on the LHe cooled panel are absorbed.

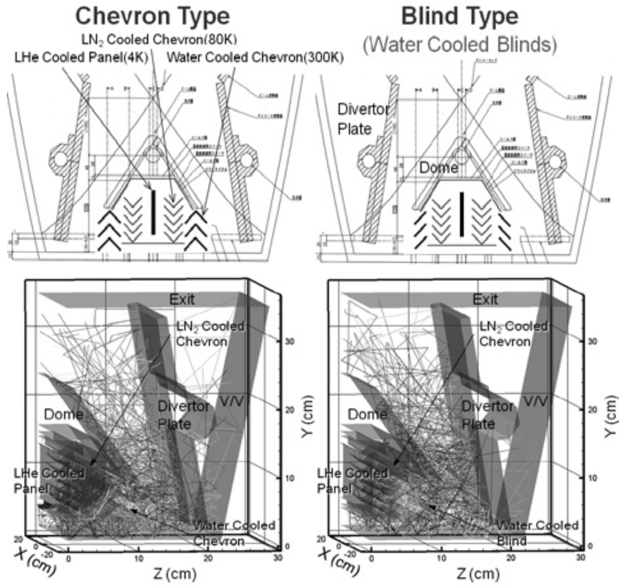

Fig. 1 Models of the components of the CHD and the pumping system for the neutral particle transport simulation (chevron type (left), and blind type (right)).

Figure 2 gives the histograms showing the heat load on the components of the vacuum pumping system with and without the effect of reflection of the atoms. In this calculation, R_{ref} is set to 0.9, and the heat load is calculated by the summation of the deposited energy by neutral particles. The heat load on the LN_2 cooled chevron in the blind type is much larger than that in the chevron type. The heat load on the LHe cooled panel in the blind type is as twice as that in the chevron type. When a pumping rate of 1.0×10^4A is necessary during plasma discharge operation, total heat load on the LHe cooled panel in the case with the reflection effect is estimated to be 1100W (chevron type) and 1390W (blind type), respectively. Formation of co-deposition layers on the surface of the components may drastically decrease (~1 order) the heat load on the LHe cooled panel by reduction of the reflection of high energetic atoms produced by charge exchange reaction with plasmas in the divertor leg as shown in this figure.

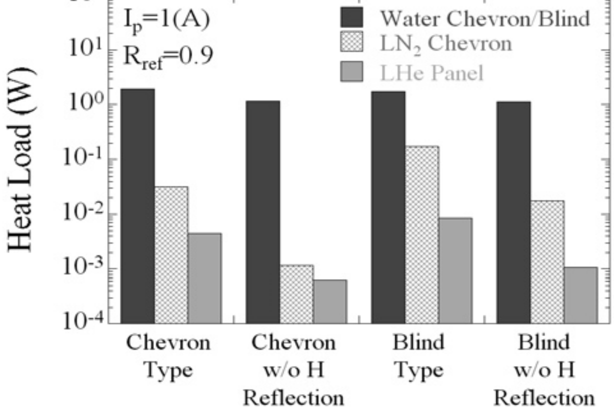

Fig. 2 Histograms of the heat load on the components of the vacuum pumping systems in the case with and without the effect of reflection of hydrogen atoms.