§1. Design of the Closed Helical Divertor Configuration in LHD

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The modification of the open helical divertor (HD) to the closed HD in the Large Helical Device (LHD) heliotron has been investigated using fully three-dimensional neutral transport code EIRENE, to accomplish the active particle control to improve plasma confinement and to sustain high performance long pulse discharges. For the first step to the full closed HD, the torus-inboard side divertor is planned to be modified. The exploring of the structure has been conducted using EIRENE code by trial and error. The code was examined in advance by comparing to spectroscopic observations, and the results of calculation agreed well with the observations. Results of the exploring show that proper rearrangement of divertor plates and additional components, such as dome structure, make the neutral particles to be compressed in the divertor region, and that makes the effective divertor pumping to be possible. Based on the simulation and experimental results, design and installation of closed HD is programmed in LHD.

In LHD, plasma experiments have been conducted under the HD configuration without divertor pumping. It has been observed in the LHD that the increase of the neutral pressure in the vacuum vessel causes degradation of plasma confinement. It has also been observed during long pulse discharge experiments that outgassing in the HD and/or impurities release from the HD causes the termination of discharge. These observations suggest that the active particle control is necessary for farther improvement of the LHD plasma parameters. To exhaust 10 Pa·m^3/s of H_2 flux corresponding to averaged fueling flux with repetitive hydrogen ice-pellet injection (10 Hz, 2 Pa·m^3 (H)/pellet) preparing for long pulse discharge experiment is a target value of the divertor pumping. To achieve the target exhaust flux using realistic pump system, such as in-vessel cryogenic pumps, the neutral pressure in the HD has to be 10 times risen, and the closure of the HD with proper structure is necessary for the pressure rise.

Figure 1 shows the calculated averaged hydrogen molecule density at the position where the pump is planned to be installed for various divertor configrations. In these calculations, we assumed that plasma parameters are constant in divertor legs, and no plasma flow. In Fig. 2, (a) is the present divertor configuration. In the case of (b), divertor plates position is same as (a), and baffle plates and dome structure are added. In the cases of (c) and (d), divertor plates are rearranged, and their surfaces are not faced to core plasma region to reduce direct loss of recycled particles. The difference between (c) and (d) is without and with dome structure. From these calculations, we found that: 1) The width of throat of baffle plates, δ, affects the density weakly.

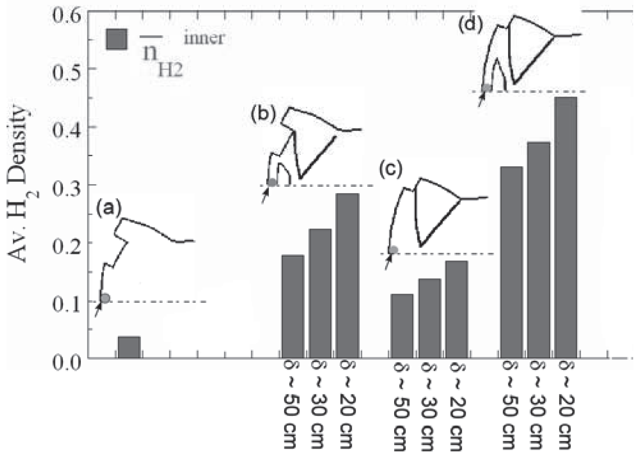

Fig. 1. Averaged hydrogen molecule density in various divertor configurations which were examined. Insertions show the divertor configurations in a holizontally elongated cross-section (above the equatorial plane); (a) open divertor (present config.) (b) (a) + dome and baffle plate (c) rearrangement of divertor plates + baffle plate. (d) (c) + dome. Baffle plates and dome are shown by white lines and blocks. δ is the width of throat of baffle plates.

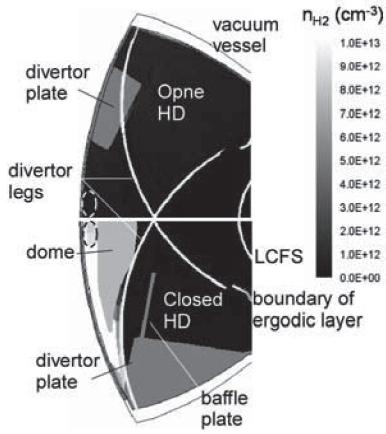

Fig. 2. Hydrogen molecule density distributions in the present open divertor (upper part) and the latest design of the closed divertor (lower part).

2) The main role of the dome structure seems to be reducing the volume of the divertor region. 3) Comparison of (b) and (d) shows that about two times higher density in (d) case for the rearrangement of the divertor plates. Figure 2 shows both the present open divertor and latest design of closed divertor as the result of the exploring. In the closed HD, divertor plates face to torus-inboard vacuum vessel, and dome structure is installed in the private region. The width of the throat of baffle plate is about 50 cm to avoid leading edge problems. In the closed HD, the density at the position where pump will be installed (space between the dome and inboard-side vacuum vessel in closed HD case, indicated by black circle) is about 20 times higher than that in present HD case (indicated by white circle), that means this closed HD design meets the required neutral pressure.