§3. Global Particle Balance in Quasi-steady State Discharge with High-density Plasma

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Zero-dimensional global particle balance in high-density-plasma discharges is investigated toward the sustainment of a high performance plasma in LHD. In LHD, a quasi-steady state with a super-high-density plasma has been attained for over five seconds by the hydrogen ice pellets. However, some critical issues to be solved are found as follows; (1) The electron density of the plasma peripheral region increases and the central electron density decreases with time in spite of the feedback control of a constant electron density, resulting that it is difficult to maintain the super-high-density plasma such as Internal Diffusion Barrier (IDB). (2) The interval of the pellet injection increases and the increase of the neutral pressure is also observed.

In this study, the zero-dimensional global particle balance in the high-density-plasma discharge is evaluated using following equation[1].

$$\int \Gamma_{\rm pellet} dt = N_{\rm plasma} + N_{\rm neutral} + N_{\rm wall} + \int \Gamma_{\rm Exhaust} dt$$
$$= \int n_{\rm e} dV + P_0 V_{\rm vessel} + N_{\rm wall} + \int S_{\rm p} P_0 dt$$

Here, $\Gamma_{\rm pellet}$ is pellet particles, $N_{\rm plasma}$ is particles inside the plasma, $N_{\rm neutral}$ is neutral particles, $N_{\rm wall}$ is exhausted particles by the wall, $\Gamma_{\rm Exhaust}$ is exhausted particles by the main pumping system of LHD. P_0 is the neutral pressure measured at a cold cathode gauge installed in the vacuum vessel. $S_{\rm p}$ is pumping speed and 295 m^3/s is used.

Figure 1 shows the result of the zero-dimensional global particle balance in three cases of the feedback control of the electron density. When the averaged electron density is maintained in the rage between 6×10^{19} and 1.5×10^{20} m^{-3}, 80 % of pellet particles is exhausted by the vacuum vessel wall and 10 % is exhausted by a main vacuum pumping system of LHD in any case, meaning that 90 % of the pellet particles is effectively exhausted. In other words, the control of the rest of the particles (10 %) is important to the sustainment of high-density-plasma. Especially, the control of the neutral particles is critical.

Figure 2 shows the relationship between neutral particles and the electron density at the peripheral region. The increase of the neutral particles causes the increase of the electron density at the peripheral region, resulting that the reduction of the central electron density at the latter phase of the discharge arises. To prevent the reduction, the control of neutral particles by a baffle-structured closed helical divertor with cryopump system will be required.

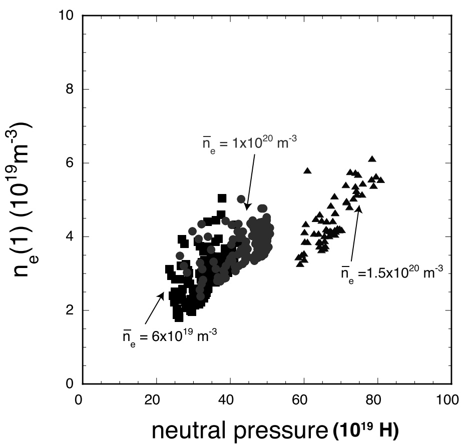

Fig. 2: Relationship between neutral particles and the electron density at peripheral region.

1) R. Sakamoto et al., PSI 2008.

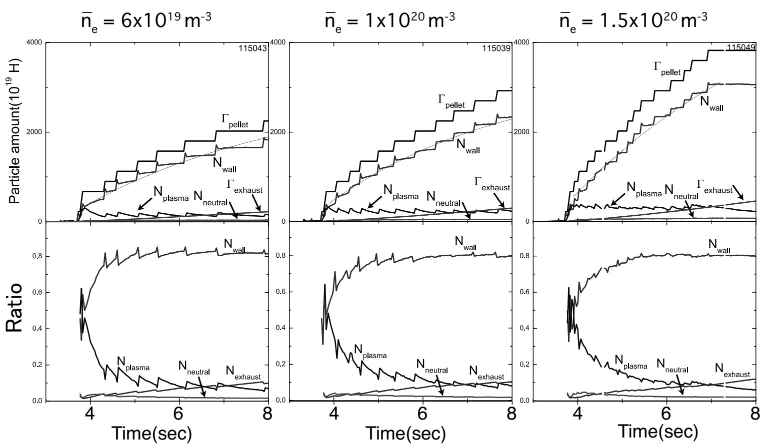

Fig. 1: Result of zero-dimensional global particle balance in three cases of the feedback control of the electron density.