§22. Study on Hydrogen Recycling in LHD

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Hydrogen recycling is one of most important issues for achievement of the stable steady state operation in a future fusion device. An objective of this research is to study hydrogen recycling properties in LHD from both a macroscopic viewpoint and a microscopic viewpoint. In this time, we studied global particle balance focusing on density clamping during electron cyclotron heating (ECH). The density clamping phenomenon is well known and has been actively studied so far but there is almost no study from the viewpoint of hydrogen recycling during the density clamping.

Global particle balance is analyzed using the following equation:

$$\frac{dN_i}{dt} + \frac{dN_0}{dt} = \Gamma_{fueling} + \Gamma_{pump} + \Gamma_{wall}, \qquad (1)$$

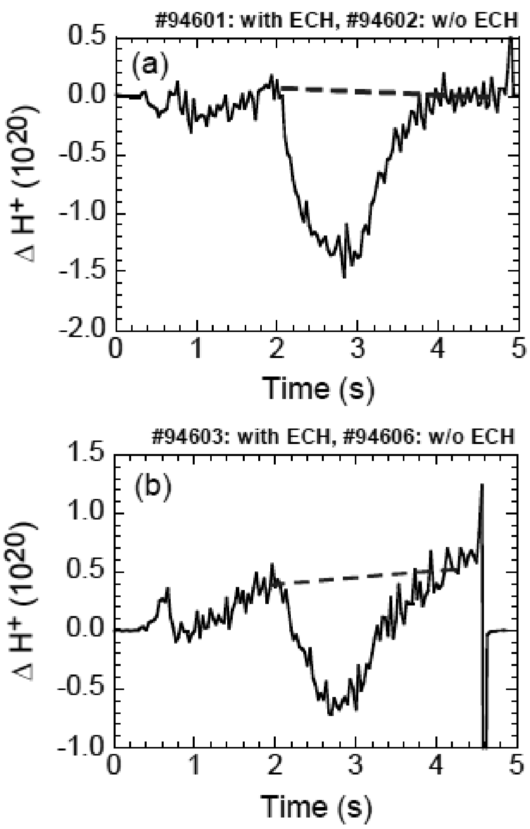

Fig.1 Time evolution of difference in total number of hydrogen ions in the plasma between discharges with and without ECH. (a)Low density plasma and (b) high density plasma. ECH power was applied to the NBI plasma from 2 s to 3 s.

where $N_{\rm i}$ and N_0 are the total number of ions and neutral particles, respectively, and $\Gamma_{fueling}$ is a fueling rate, Γ_{pump} is a pumping rate of external pump units and Γ_{wall} is a wall pumping rate. $N_{\rm i}$ is assumed to be the same as the total number of electrons in the plasma.

Figure 1 shows time evolution of difference in total number of hydrogen ions in the plasma between discharges with and without ECH. The ECH power of 1.1 MW was applied from 2 s to 3 s to low density (~1.5 × 10^{19} m^{-3}) and high density (~3.0 × 10^{19} m^{-3}) plasmas, which were sustained by NBI (P_{NBI} ~ 2MW). In the case of the low density plasma, the decrement of the total number of hydrogen ions in the plasma (density clamping amount) was ~1.4×10^{21}. In the case of the high density plasma, on the other hand, it was ~1.1×10^{21}. It was 20 % smaller than that of the low density plasma. The density clamping occurred in both low and high density plasma but their recycling properties were quite different. The particle balance analysis using the equation (1) indicates that the density clamping amount was pumped by the wall for the low density plasma, but for the high density plasma the density clamping amount was sustained as the increment of neutral hydrogen contents in the vacuum region not in the wall.

Figure 2 shows that time evolution of edge plasma density, which was estimated by the Thomson scattering measurement, and neutral hydrogen contents of the vacuum region in the high density plasma. The edge density did not increase but it decreased a little during ECH even though the neutral hydrogen contents in the vacuum region increased. This suggests that ECH prevents hydrogen neutrals from penetrating to the plasma. This should be studied in more detail.

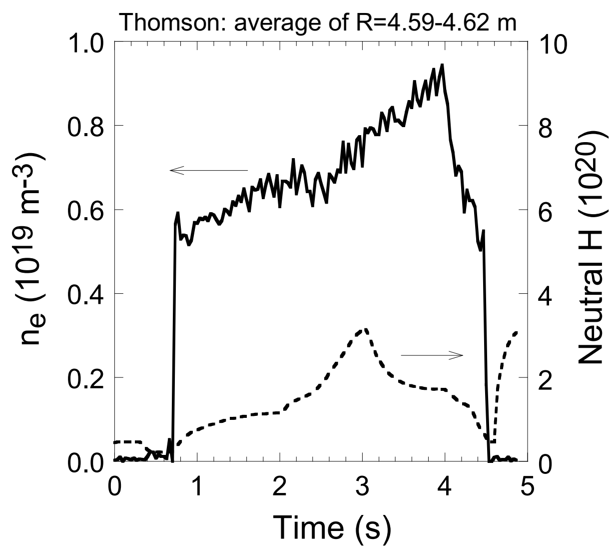

Fig. 2 Time evolution of edge plasma density and neutral hydrogen contents of the vacuum region in high density plasma. ECH power was applied to the NBI plasma from 2 s to 3 s.