§64. Particle and Power Balance Study in Long Pulse Discharges on LHD

Nakamura, Y., Suzuki, H., Oka, Y., Osakabe, M., Peterson, B.J., LHD Experimental Groups

Particle and power balance in long pulse discharges heated by NBI alone was studied. A strong wall pumping was observed for hydrogen discharges. The study of power balance showed that metal impurity radiation was remarkably reduced by the installation of graphite divertor tiles. A new density dependence of radiation, which indicated the saturation of radiation in high density region, was also found for discharges with graphite tiles.

Particle balance was investigated for helium and hydrogen discharges with a feedback control of the plasma density. It is clear that there is a great difference in wall pumping between helium and hydrogen discharges. In helium discharges, the plasma density was built up by the gas puffing and the resulting plasma inventory was almost the same as the integrated gas input. In addition, the gas puff was not required after the density build-up phase. On the other hand, as shown in Fig. 1, the gas required during the density build-up was significantly higher for hydrogen discharges, and the gas puff with the rate of about 1.2 Pam^3/s was needed to maintain the density. Most of the input gas was absorbed by the wall and the wall inventory showed a net increase of 23 Pam^3/s at the end of the discharge. It is evident that the wall pumping was strong in the plasma build-up phase and still effective at the end of the discharge.

In power balance study, the radiated fraction was investigated for long pulse discharges with stainless steel divertor plates and graphite tiles. Figure 2 shows the dependence of the radiated fraction on the line integrated electron density. In the 2nd experimental campaign, the radiation power rapidly increased with the density because of the high concentration of metal impurities (mainly iron) most likely due to the sputtering of stainless steel divertor plates. In these discharges, the metal impurities accumulated in the plasma. When the density was increased, there occurred a relaxation oscillation phenomena ("breathing"), where expansion and contraction of the core plasma was repeated with a period of 1~2 s. As a result, the plasma density in long pulse operation was limited to less than 10^{19} m^{-3}. This limitation can be evaluated by global power balance. When the total radiation increases with the density and it reaches to about 85 % of deposited heating power, a minor radiative collapse due to the light impurities (C, O) occurs in the peripheral region and the hot plasma core contracts. After installation of graphite tiles along the divertor legs, no "breathing" plasma has been observed even in the same magnetic configuration (R = 3.75 m, B = 1.5 T). Then a remarkable reduction of core radiation was observed. Moreover, the long duration plasmas revealed a new feature on the density dependence of the fraction of radiated power. The radiation loss increased with the density up to 3.5 x 10^{19} m^{-3} and remained constant there. The saturated level was 40 % for helium discharges in the magnetic configuration of R = 3.75 m and B = 1.5 T. The same density dependence was also observed for hydrogen discharges in the different magnetic configuration (R = 3.6 m, B = 2.75 T). The saturated level was about 30 % lower than that for helium discharges. This difference can be attributed to the magnetic configuration and the strong magnetic field. To understand this saturation mechanism, further analytical and experimental investigation will be required.

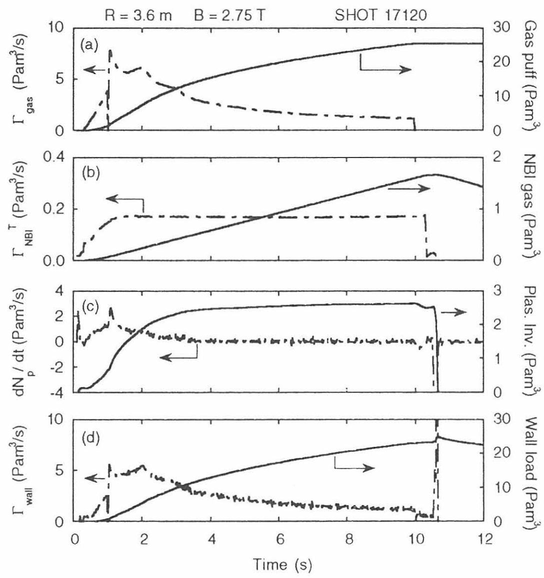

Fig. 1 Particle balance for hydrogen discharge: (a) gas puff, (b) fueling by NBI, (c) plasma inventory, (d) inferred wall load.

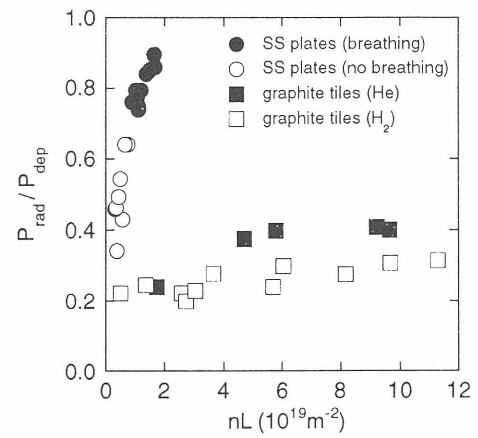

Fig. 2 Density dependence of radiated fraction