§57. Plasma Performance of LHD Long Pulse Discharges

Nakamura, Y., Kumazawa, R., Takeiri, Y., Mutoh, T., Kawahata, K., Noda, N., LHD Experimental Group

Demonstration of high confinement, long-duration discharges is one of the most challenging issues for magnetic fusion research. In LHD, our efforts towards long-pulse operation have been mainly devoted to the extension of discharge duration using both NBI and ICRF heating systems. Although we obtained good confinement plasmas in short-pulse discharges (τ_d < 3s), it is of great concern whether the improved LHD plasmas could be maintained over a period of long time.

This issue was primarily investigated using 10 s hydrogen discharges with NBI heating in the magnetic configuration with R = 3.6 m and B = 2.75 T. Figure 1 shows the dependence of normalized plasma stored energy on the line averaged electron density. The experimental range of the NBI heating power and the average electron density are $0.5 < P_{dep} < 2$ MW and $1.8 \times 10^{19}\ m^{-3} < n_{e\text{-}bar} < 6.2 \times 10^{19}\ m^{-3}$, respectively. The open circles represent the plasmas in the initial stage of the discharge (t = 2 ~ 3 s) and the solid ones the plasmas at the end of the discharge (t = 8 ~ 10 s). A scaling of the normalized stored energy can be derived from the ISS95 scaling: $W_p/P_{dep}^{0.41} = 0.11 n_{e\text{-}bar}^{0.51}$, where P_{dep} is the NBI deposition power calculated by using a shine-through power, which was measured with calorimeter arrays embedded in beam facing armor plates. The plasmas at the initial stage showed the ISS95 scaling with an enhancement factor of 1.4. As a matter of course, the enhanced confinement can be compared with that in the short-pulse discharges. On the other hand, a significant decrease of the store energy was observed after about 10 s in the density range of $n_{e\text{-}bar} = 2 \sim 4 \times 10^{19} m^{-3}$. When the density was kept constant in this region during the discharge, the plasma performance was remarkably degraded with time and the stored energy decreased up to 68 % at the end of the discharge (t = 10 s). This degradation of plasma performance can be related to the energy loss caused by the radiation due to metallic impurity accumulation. Figure 2 shows a relationship between the enhancement factor in τ_E and the radiation emissivity at the plasma center in the density ramp-up discharge (shot 17093). The radiation profile was measured by bolometer arrays. When the density increased with time, the central radiated power increased remarkably with increasing the density, thereby leading to the reduction of enhancement factor. In the high-density region, the central radiated power decreased and the plasma performance was recovered rapidly with the decrease of the radiation. The radiated power density corresponds to about 40 % of the deposited power density for electrons as shown in Fig. 3, where the deposition profiles calculated for electrons and ions are indicated together with the total deposition power and the measured radiation profile. Since electron conduction is a primary loss channel, the power balance of core plasma may be affected by the strong central radiation. If the discharges are not operated in the range of impurity accumulation density window, high confinement plasmas can be sustained for long time in LHD.

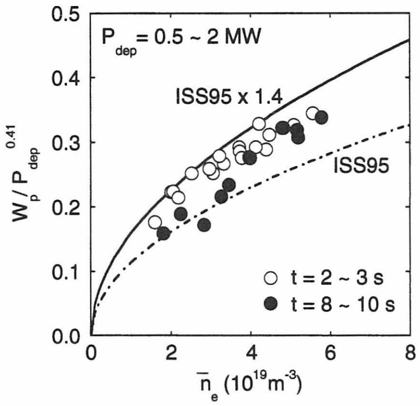

Fig. 1. Dependence of stored energy on line-averaged electron density.

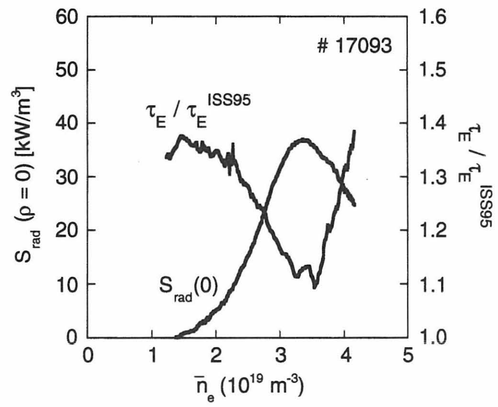

Fig. 2. Correlation between plasma performance and central radiation.

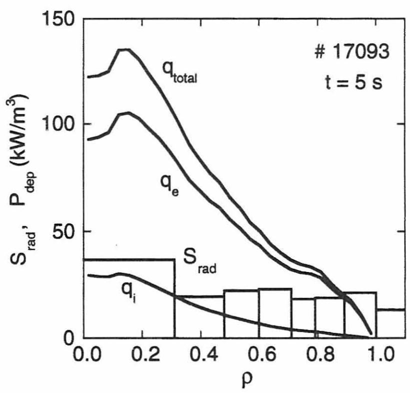

Fig. 3. Profiles of radiation and power density deposited by NBI heating.