# §15. High Efficiency Fueling by Pellet Injection and Its Effect on Extension of Operational Region in LHD

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Multi pellet injection experiment was carried out in the third campaign of LHD experiment. Pellet injection has extended an operational region of NBI plasmas to the higher density area compared with gas puffing.

The fueling pellet injector is equipped with 5 independent barrels. The size and velocity of the pellet are 3 mmϕ × 3 mmℓ (cylinder) and 1 km/s, respectively.

Waveforms of a typical discharge with pellet injection (#15440, $B_t = 2.75$ T, $R_{ax} = 3.6$ m, $P_{NBI} = 4$ MW) are shown in Figure 1. Pellet injection is carried out at 0.8, 0.88, 0.96, 1.04 and 1.12 s. The line-averaged electron density increases sharply at the time of injection, making the increase rate of the stored energy larger. Figure 2 shows the dependence of the plasma stored energy on the line averaged electron density. At the timing of injection, the pellet ablates adiabatically and thereby the density increases without the change of the plasma stored energy. Then the stored energy increases for all density-decay phases, and intrinsic confinement is recovered after pellet ablation in the high density regime. Ablation trace measurement by using the Hα emission indicates that the pellet penetration reached the center region of plasma, but measured density profile shows typically a hollow profile. It was indicated that the pellet mass redistribution in a brief time scale (<100 μs) occurred. Although the density profile becomes hollow just after the pellet ablation, the density profile changes to peak in the density decay phase. The peaking factor defined by $n_e(0)/\langle n_e \rangle$ is increased up to 2 after the pellet injection, which suggests the improvement of particle confinement or generation of inward pinch.

Figure 3 shows the stored energy as a function of the density. Open circles and closed circles are data obtained by gas puffing and by pellet injection, respectively. The dashed line indicates calculated stored energy assuming that the energy confinement time is 1.5 times longer than that obtain from ISS95 (the international stellarator scaling 95) with heating power of 4 MW. In the case of gas puffing, the achievable maximum density is $0.5\times10^{20}$ m$^{-3}$ and the confinement deterioration is observed at densities above $0.35\times10^{20}$ m$^{-3}$. A major cause of this degradation is due to the excess neutrals injected by strong gas puffing which is necessary to increase the density in a limited pulse duration. In the case of pellet injection, confinement deterioration is not observed and the stored energy reaches 0.88 MJ. Since the fueling efficiency by pellet injection is much better than that by gas puffing, the resultant suppression of neutrals extends the density limit. The achieved maximum density with pellet injection is $1.1\times10^{20}$ m$^{-3}$.

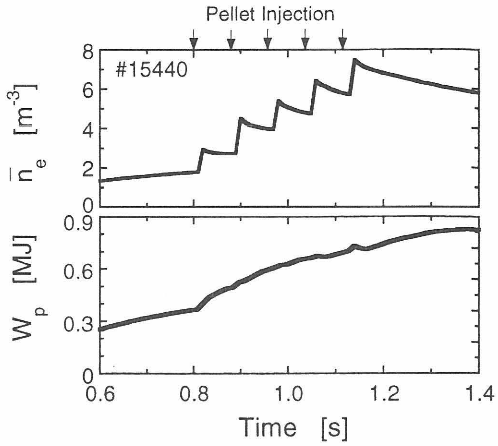


Fig. 1. Temporal evolution of electron density and plasma stored energy. Pellet ware injected at 0.8, 0.88, 0.96, 1.04 and 1.12 s.

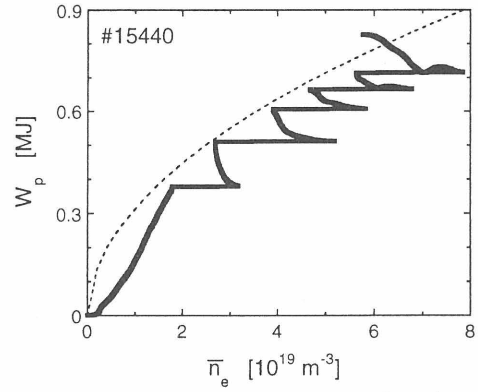


Fig. 2. Plasma stored energy as a function of line averaged electron density.

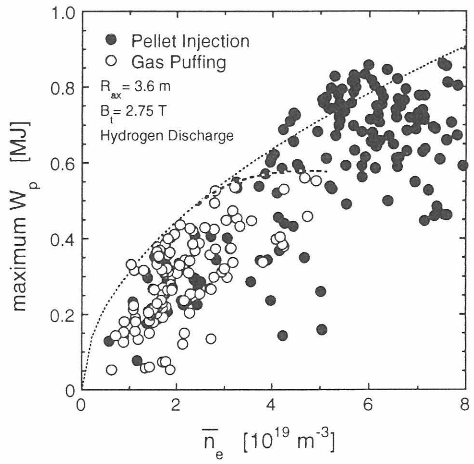


Fig. 3. Maximum plasma stored energy versus line averaged electron density. Open circle symbol and close circle symbol shows data of gas puffing and pellet injection, respectively.