§1. High $W_p$ Operation in LHD

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The diamagnetic energy ($W_p$) is one of the most important parameters representing the plasma performance, since the $W_p$ is a volume integral of the product of density and temperature. We have tried to improve the $W_p$ of LHD plasma by using the hydrogen ice pellet injection and the NBI heating. The operation scenario for the high $W_p$ is as follows: (1) initiating the plasma by the first NBI; (2) injecting ice pellets into plasma; (3) heating the plasma by the second NBI; (4) recovering the plasma with the reheat mode. In order to deposit the fuel particle at the plasma center, the $T_e$ should be reduced, and the useful technique is the multiple pellet injection into the plasma sustained by a single beam. This is also useful to deposit the heating power into the plasma center.

The first NBI starts at 0.3 s and the first pellet is injected at 0.6 s. Then 8 pellets are injected sequentially. Fig. 1(a) shows the $W_p$ versus interval of pellet injection in the case of counter dominated NBI. Fig. 1(b) shows the $W_p$ versus the timing of the second NBI. Fig. 1(c) shows the $W_p$ versus the timing of the second NBI in the case of co dominated NBI.

Fig. 2 shows waveforms of the heating power, the electron temperature ($T_{eo}$), the line averaged electron density ($<n_e>$), and $W_p$. The plasma is initiated the residual gas and the first NBI. In the case of the sequential pellets are injected (solid line), the $T_{eo}$ drops to bottom due to first a few pellets. So, several pellets can reach the plasma center. The $W_p$ starts to increase when the second NBI starts. The $W_p$ still increases at $t=1$ s with the sequential pellet, while it starts to decrease at $t=1$ s without sequential pellets (broken line).

This experiment indicates that the high $W_p$ can be obtained by the second NBI heating just after the hydrogen ice pellet injection. As increasing the NBI power, high $W_p$ plasma can be obtained by injecting additional hydrogen pellets. No significant instability has been observed in high $W_p$ operations in LHD. Easy operation is an advantage of helical systems.