§8. Impurity Pellet Injection with Z=6-74 for Improvement of Plasma Performance in LHD

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In helical plasmas experiments on pellet injection have been extensively done in relation to the study of high-density operation with improvement of plasma performance because the current-driven instability can be basically ruled out. Impurity pellets with atomic number of Z=6 to 74 have been injected in NBI H_2 plasmas of Large Helical Device (LHD) and the plasma response has been studied in high density regions.

The size and speed of injected pellets range in 0.3-1.8mm depending on Z and 100-300m/s depending on weight and size, respectively [1]. Heavier pellets generally have lower speed. The plasma response after the pellet injection has been investigated in relation to the size and density rise systematically changing the Z number (H, C, Al, Ti, Fe, Mo, Sn and W). The results are shown in Figs.1 (a) and (b). Maximum size of the pellets, S_{max}, which can maintain a discharge without plasma collapse under P_{in}~10-18MW, is 3.4^{ϕ}mm×3.4mm^{L} in cylinder for an H_2 ice pellet and 1.8^{ϕ}mm×1.8mm^{L} for a carbon pellet. The 3.8mm H_2 and 2.0mm carbon pellets were tried, but the smooth operation of discharges was a little difficult. The S_{max} of course decreases with Z, i.e., ~1mm for Al and Ti and 0.2-0.3mm for Mo and W. The density rise, Δn_e, is close to 10×10^{14}cm^{-3} for single H_2 and carbon pellet injection. However, the upper limit of Δn_e reduces down to 1×10^{13}cm^{-3} for Al pellet.

The radial deposition of the impurity pellet is mainly determined by heat flux from fast ions of NBI in LHD [2]. When the main heating power is injected just after the C pellet, the central deposition can be achieved with extremely hollow T_e and peaked n_e profiles. The hollow T_e profile is kept during 50ms after the pellet injection and begins to recover the peaked T_e profile. Here, remarkably important thing should be mentioned that the discharge is quite stable even in such a hollow pressure profile case. In relation to this, MHD stability has been examined in NBI discharges with plasma collapse after pellet injection. The spherical Mo pellet with a diameter of 0.5mm is used for the purpose. After the injection the beta value measured from diamagnetic loop decreases monotonically whereas the density gradually goes up and keeps a constant density increment until the complete disappearance of the plasma energy. The decay time of the plasma energy is approximately equal to τ_E of the discharge (~50ms). In such collapsed phases any strong MHD mode excitation has not been observed. It is thus concluded that the plasma collapse following after the impurity pellet injection is not induced by the MHD instability. The collapse is caused by the radiation loss during ionization phase after pellet ablation [3].

The plasma performance after C pellet injection is compared with gas puffing and H_2 pellet injection as shown in Fig.2 (R_{ax}=3.60m). The W_p is scaled by the Stellalator scaling of ISS95 to eliminate the difference in the NBI input power ($5\le P_{NBI}\le 18$MW). In case of the pellet injection the maximum W_p observed during the density decay phase are plotted. The data for the H_2 pellet are obtained from multi-pellets injection, whereas those for the C pellet are from single-pellet injection. The operational range is then different for each other (C: 2-4x10^{13}cm^{-3}, H_2: 4-10x10^{13}cm^{-3}). In LHD the confinement improvement has been observed so far compared to the ISS95-scaling, as indicated with "1.5×ISS95". The performance on the present C pellet injection also shows the similar confinement to the H_2 pellet.

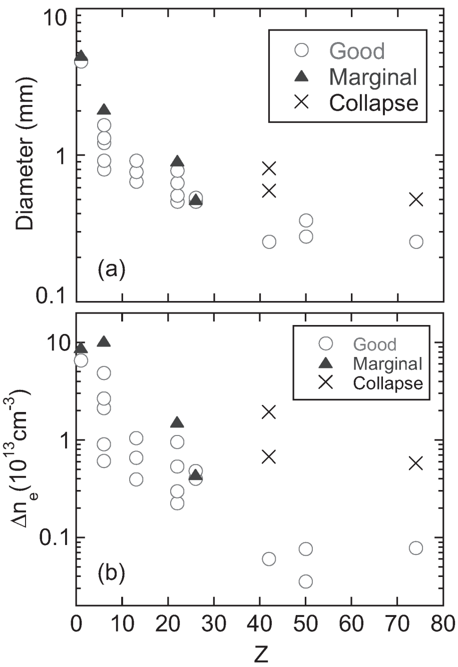

Fig.1 Plasma response after pellet injection (H, C, Al, Ti, Fe, Mo, Sn and W); Z dependence for (a) diameter and (b) density rise.

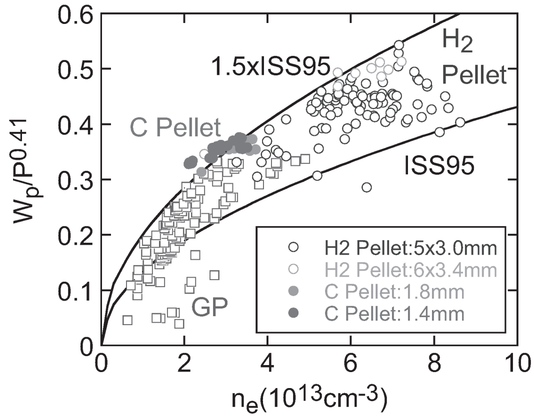

Fig.2 Performance of C pellet injection normalized by ISS95 input power scaling (W_p[MW], P [MW]). C pellet injection is done under P_{tot}=17MW including P_{perp}=4MW.

1) H.Nozato, S.Morita, M.Goto et al., RSI 74 (2003) 2032.
2) S.Morita, Y.Shirai, M.Goto et al., NF 42 (2002) 876.
3) S.Morita et al., Proc. EPS Conf., Creta, Greece (2008).