§18. Reduction of Divertor Heat and Particle Loads with Neon Seeding

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Reduction of heat and particle loads to divertor is a crucial issue to realize fusion reactor. Divertor detachment is a favorable operation for the purpose. To achieve divertor detachment, reduction of electron temperature ($T_e$) in scrape-off-layer (SOL) is necessary. In present medium/large fusion devices, plasma facing material has been carbon, and carbon works as dominant radiator for reduction of $T_e$. However, carbon will not be utilized in fusion reactor to reduce tritium retention in vacuum vessel and to avoid large erosion of plasma facing components, and metallic material such as tungsten will be plasma facing material. Therefore, it is considered that impurity such as neon seeding is necessary to enhance radiation loss in SOL. In tokamaks, impurity seeding experiment has been conducted, and reduction of $T_e$ in SOL has been observed.\(^1\) Against this background, neon seeding experiment was conducted in LHD which has unique magnetic field line structure such as existence of stochastic layer in SOL.

Figure 1 shows time evolutions of plasma parameters in a Ne seeding discharge with line average density ($n_{e,\text{bar}}$) of $5\times10^{19}$m$^{-3}$. Ne gas-puffing was conducted from $t = 4$ s for 120 ms. The Ne gas flux was $\sim 1.6$ Pa·m$^3$/s, and it is about 10 % of H$_2$ gas flux at $t = 4$ s. Total radiation power ($P_{\text{rad}}$) rose from 2 MW ($-0.15\times P_{\text{NBI}}$) to 4 MW ($-0.3\times P_{\text{NBI}}$) during Ne puffing. It is clearly shown that both divertor electron density ($n_{e,\text{div}}$) and $T_e$ ($T_{e,\text{div}}$) decreased with Ne seeding. That means particle and heat loads to divertor were reduced. Ne seeding did not affect strongly global parameters such as plasma stored energy and $n_{e,\text{bar}}$. Figure 2 shows modification of the radial profiles of electron density ($n_e$) and $T_e$, respectively, due to the Ne seeding. In SOL and near LCFS in core plasma, $n_e$ slightly increased, but center $n_e$ did not change. Figure 2(c) shows $T_e$ ratio between after and before Ne seeding. It is shown that $T_e$ decreased in SOL, but there was almost no change in core plasma as $n_e$ profile. They are good features of Ne seeding. Ne seeding in low density discharge ($n_{e,\text{bar}} \sim 2\times10^{19}$m$^{-3}$) was also conducted, and reduction of divertor loads was also observed. In this case, $P_{\text{rad}}/P_{\text{NBI}}$ reached 0.5, though $n_e$ and $T_e$ in peripheral region in core plasma increased and decreased, respectively.

Ne seeding was also applied to Super Dense Core (SDC) discharges with pellet fueling,\(^2\) and reduction of the divertor loads was confirmed.

In LHD, other methods to reduce the divertor loads such as divertor detachment with magnetic island formation\(^3\) and SERPENS mode\(^4\) have been conducted. But they cannot be applied to inward shifted magnetic axis configurations up to now, and they need high density plasma. It should be noted that Ne seeding can be applied to inward shifted configurations and relatively low density plasma ($n_{e,\text{bar}} \sim 2\times10^{19}$m$^{-3}$).