§6. Comparisons of Density Profiles in JT-60U Tokamak and LHD Helical Plasmas

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It is important for prediction of fusion performance in a fusion reactor to understand mechanisms for determining density profiles systematically in toroidal plasmas. In this section, dependence of density profile peakedness was investigated in JT-60U tokamak and LHD helical plasmas. In ELMy H-mode plasmas on JT-60U, it has been found that a density peaking factor increases with decreasing collisionality.[1] Dependence of the density peaking factor on the effective collisionality, which provides an estimate of the growth rate of drift wave instabilities,[2] is consistent with the interpretation that anomalous inward pinch driven by turbulent transport significantly affects the density peaking. In LHD plasmas, it has been found that the density peaking factor decreases with decreasing electron-ion collision frequencies normalized by the collisionality for an upper boundary of the 1/ν region, ν^*_h, for the magnetic axes of 3.6, 3.75 and 3.9 m. This result indicated that neoclassical transport enhanced by helical ripples largely affects the density profile in LHD plasmas, while this collisionality dependence was less pronounced for the LHD plasmas having small effective helical ripples at the magnetic axis of 3.5 m ($\nu^*_h \geq 1$). Thus, density profiles in LHD plasmas tended to approach those in JT-60U as the contribution of neoclassical transport is reduced, namely by moving the magnetic axis more inward. However, the scatter of data was large indicating that the density peaking factor could also be dependent on other hidden parameters. In this section, dependence of the density peaking factor on other parameters was investigated for understanding other hidden parameters. Here, momentum input was cited as candidates of hidden parameters.

Effects of momentum input were investigated in the large volume configuration with various NBI combinations (co-, counter- and perpendicular-) in JT-60U. The density profile data analyzed here were taken before the installation of the ferritic steel tiles. Therefore, fast ion losses due to a large toroidal field ripple induced counter toroidal rotation. The momentum input was scanned by changing the combination of tangential NB (co- and counter-) with perpendicular NB. The absorbed power was almost kept constant at 6-8 MW. The density profile was clearly peaked in the central region for the counter-injection as shown in Fig. 1 (a), while electron temperature profiles were unchanged (see Fig. 1 (b)). The toroidal rotation profiles were quite different for both cases in the whole plasma region, as shown in Fig. 1 (c), although the density profiles were same for both cases in the region of $r/a \geq 0.6$. This result indicates that there are other hidden parameters for restricting the density profile in the region of $r/a \geq 0.6$ and/or that the momentum input affects the density profile only in the region of $r/a \leq 0.6$. The toroidal electric field is larger for the counter-injection than for the co-injection. However, Ware pinch velocity (~0.02 m/s at r/a=0.3) is one order of magnitude lower than particle source induced flux velocity (Γ/n), indicating small contribution of Ware pinch effects to determination of density profiles.

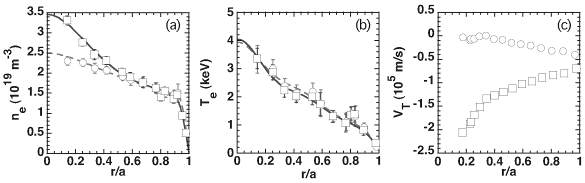

Fig. 1 (a) Electron density profiles, (b) electron temperature profiles and (c) toroidal rotation profiles in JT-60U ELMy H-mode plasmas. Circles and dashed line show the data with counter-NB and square and solid line show the data with co-NB.

In LHD plasmas, density profiles also tended to be peaked with counter-NB injection. In the discharge shown in Fig. 2 (a), NB injection was changed from co- to counter-injection at t=4 s. The plasma current was changed from +60 kA to -70 kA. With co-NB injection, density profile was hollow as shown in Fig. 2 (b). After switching to counter-NB injection, central density increased and the peaked density profile was formed. The electron temperature profile became flat with counter-NB injection as shown in Fig. 2 (c). Safety factor was also modified due to NB current drive as shown in Fig. 2 (d). In helical plasmas, toroidal rotation is small compared with that in tokamak plasmas. Thus, the electron temperature gradient and/or magnetic structure could affect to density profiles. These results indicated existence of hidden parameter responsible for determining the density profile in both tokamak and helical plasmas.

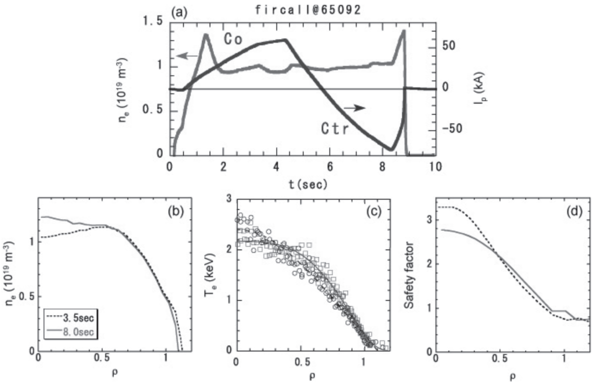

Fig. 2 (a) Time evolutions of line averaged density and plasma current in the discharge where NB injection direction was scanned. (b) Electron density profiles, (c) electron temperature profiles and (d) safety factor profiles in LHD plasmas. Dotted lines and circles show the data with co-NB injection. Solid line and squares show the data with counter-NB injection.

1) Takenaga, H. et al., : Nucl. Fusion, 48 (2008) 075004.
2) Angioni, C. et al., : Phys. Rev. Lett, 90 (2003) 205003.