§9. Comparisons of Density Profiles in JT-60U Tokamak and LHD Helical Plasmas with Low Collisionality

Takenaga, H., Urano, H. (JAEA), Muraoka, K. (Chubu Univ.), Tanaka, K., Yokoyama, M.

Comparative studies between tokamak and helical plasmas are important for understanding both unique physics depending on each magnetic configuration and common physics in a toroidal system. Comparisons of density profiles in both plasmas are placed in an attractive research area, because the density profile is considered to be related with both unique and common physics. Neoclassical particle transport in a low collisionality regime of the helical plasmas is significantly different from that of the tokamak plasmas. In the helical plasmas, a 1/ν regime exists due to a helical ripple, where the neoclassical diffusivity and convection velocity are inversely proportional to the collisionality, and the neoclassical transport is enhanced in the non-axisymmetric helical plasmas from a level of the axisymmetric tokamak plasmas.[1)] In this regime, the outward convection velocity driven by the neoclassical transport increases with decreasing the collisionality. On the other hand, the anomalous transport in both plasmas involves common physics in a toroidal system. Drift wave instabilities such as ion temperature gradient (ITG) mode and trapped electron mode (TEM) could be important for the particle transport in both plasmas.[2)]

Figure 1 shows dependence of a density peaking factor on an electron-ion collisionality (ν_{ei}) normalized by a trapped electron bounce frequency as follow,

$$\nu^*_b=\nu_{ei}/(\varepsilon_t^{3/2}v_T/qR), \qquad (1)$$

where ε_t is an inverse aspect ratio, v_T is an electron thermal velocity, q is a safety factor and R is a major radius. The value of ν^*_b was calculated using the parameters at r/a = 0.5. The regions of $\nu^*_b < 1$ and $\nu^*_b > 1$ correspond to the banana and plateau regimes, respectively. The density peaking factor is defined as a ratio of the electron density at r/a = 0.2 to the volume averaged density. The density peaking factor increases with decreasing the collisionality in JT-60U ELMy H-mode plasmas (I_p = 1.0 MA, B_T = 2-2.1 T). In ASDEX-U and JET, it was found that the density peaking factor increases with decreasing the collisionality due to an anomalous inward pinch induced by ITG/TEM turbulence.[3)] The collisionality dependence of the density profile in JT-60U could be related to the anomalous inward pinch similar to the ASDEX-U and JET results. In the LHD plasmas at Rax = 3.5 m (B_T = 2.8 T), the density peaking factor also increases with decreasing the collisionality as similar to the JT-60U data. In contrast, the density peaking factor decreases with decreasing the collisionality in the LHD plasmas at Rax = 3.6 m (B_T = 2.75, 2.8 T). In this case, the density profile is changed from a peaked profile to a hollow profile. In the LHD plasmas, the collisonality dependence is reversed depending on the magnetic axis. The perturbative particle transport analysis in LHD indicated that the particle diffusivity is anomalous in the wide collisionality region.[4)] Therefore, the different collisionality dependence shown in Fig. 1 could be ascribed to the change in dominant transport process for producing the convection velocity.

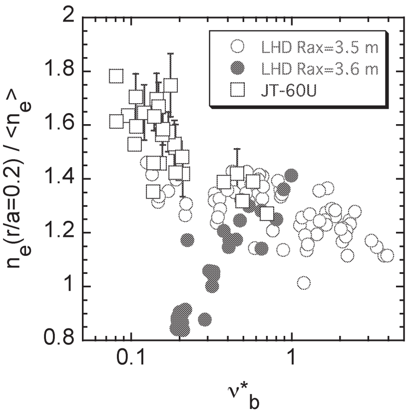

Fig. 1 Density peaking factor as a function of ν^*_b.

Figure 2 shows the dependence of the density peaking factor on the normalized collisionality defined as,

$$\nu^*_h = \nu_{ei}/(\varepsilon_h^{3/2}v_T/qR), \qquad (2)$$

where ε_h is a helical ripple. This normalized collisionality is used for an index of boundary at the 1/ν regime. Since the data are not in the 1/ν regime for both Rax = 3.5 m and Rax = 3.6 m, the different collisionality dependence can not be explained by the different collisionality regime. Neoclassical transport is larger at Rax = 3.6 m than at Rax = 3.5 m in the plateau region, while it is similar for Rax = 3.5 and 3.6 m in the 1/ν region.[1)] The collisionality dependence of the density profile at Rax = 3.5 m could be determined by the anomalous inward pinch, similar to that in JT-60U, due to the smaller neoclassical transport. On the other hand, the density peaking factor is well correlated with ν^*_h at Rax = 3.6-3.9 m even above $\nu^*_h > 1$ as shown in Fig. 2. The collisionality dependence could be related to the neoclassical outward convection velocity at Rax = 3.6-3.9 m due to the large neoclassical transport enhanced by the large helical ripple in the outward shifted configuration.

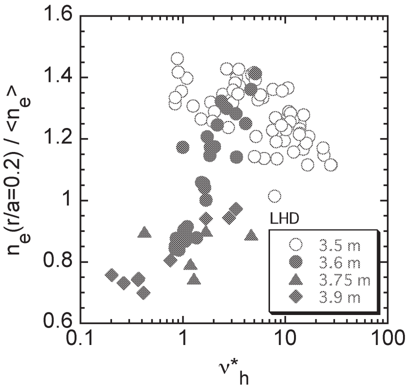

Fig. 2 Density peaking factor as a function of ν^*_h.

References

1) Murakami, S. et al., Nucl. Fusion, 42 (2002) L19.
2) Yamagishi, O. et al., Phys. Plasmas, 14 (2007) 012505.
3) Angioni, G. et al., Phys. Rev. Lett, 90 (2003) 205003.
4) Tanaka, K. et al., Fusion Sci. Technol., 51 (2007) 97.