§8. Comparison of Confinement Degradation in High Density and Particle Transport between Tokamak and Helical

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A comparative study between tokamak and helical plasmas is beneficial for understanding of both common physics in toroidal system and unique physics depending on each magnetic configuration. In this study, the confinement degradation in high density and the particle transport were compared in JT-60U and LHD. In tokamaks, Greenwald density is widely used as an index for the confinement degradation in high density, although it is originally an index for the high density disruptive limit. However, physical mechanisms for the Greenwald density and the confinement degradation in high density have not been well understood yet. Therefore, dependence of the confinement on an equivalent Greenwald density determined from the rotational transform was investigated in LHD plasmas and it was compared with that in JT-60U. In addition, the particle transport was compared in plasmas heated by NBI and/or ECRF with no or small central particle source between JT-60U and LHD.

In LHD plasmas, an equivalent Greenwald density was estimated as $n_{GW}=(5/\pi)(B/R)\iota$, where B is the toroidal magnetic field, R is the major radius and ι is the rotational transform. In this study, ι at the LCFS was used, because the Greenwald density could be related to the edge density. The dependence of confinement enhancement factor (τ_E/τ_{ISS95}) over the ISS95 scaling on n_e/n_{GW} at $R_{ax}=3.6$ m is shown in Fig. 1 (a). In LHD, n_{GW} is relatively high due to the large increase in ι at the peripheral region. Therefore, n_e/n_{GW} was limited below 0.6 even near the density limit for radiative collapse in LHD. The value of τ_E/τ_{ISS95} decreased with increasing n_e/n_{GW} in the region of $n_e/n_{GW}>0.2$. In the region of $n_e/n_{GW}<0.2$, the fast ion component could affect τ_E/τ_{ISS95}. In LHD plasmas with pellet injections, the confinement degradation became weak compared with that with gas-puffing. This result was similar as that in the pellet injected tokamak plasmas. In JT-60U ELMy H-mode plasmas, the confinement enhancement factor (H_{89P}) over ITER89P scaling decreased in the region of $n_e/n_{GW}>0.3$-0.4 as shown in Fig. 1 (b). The dependence of τ_E/τ_{ISS95} on n_e/n_{GW} in LHD exhibited a similar tendency as H_{89P} in JT-60U. The comparison should be performed in future work considering density and heating profiles with the data in W7-AS and outward shifted plasmas on LHD ($R_{ax}=3.9$ m). In W7-AS, ι profile is flat and the high confinement was obtained at high density above the equivalent Greenwald density. In LHD outward shifted plasmas, τ_E/τ_{ISS95} is relatively kept at unity in the wide density region.

The particle transport was compared in the LHD plasma with NBI and ECH at B=1.54 T and $R_{ax}=3.9$ m and the JT-60U plasma with ECH at $I_p=1.2$ MA and B=3.7 T. In LHD, the hollow density profile was observed as shown in Fig. 2 (a). In JT-60U, the peaked density profile was observed even without central particle source. In JT-60U, the inward pinch velocity was necessary to reproduce the density profile [1]. In order to estimate the particle transport coefficients in the LHD plasma, the gas-puffing modulation technique was applied with a frequency of 10 Hz. The clear density perturbation was observed in the multi channel FIR interferometer signals measured vertically. The amplitude and phase difference were calculated by assuming the spatially constant diffusivity of D=0.3 m^2/s and the convection velocity shown in Fig. 2 (b) (Case 1 : inward, Case 2 : outward, Case 3 : outward in center and inward in edge). In these calculations, the ergodic layer was included in the region of $\rho=1.0$-1.3 and the radial profile of gas-puffing source was calculated from 1-D model. Figure 2 (c) and (d) show the amplitude and phase difference normalized at channel 5 of the modulated line integrated density, respectively. The calculated amplitude in the case 3 was similar as the experiment. On the other hand, the calculated phase difference in the case 1 was similar as the experiment rather than in the case 3. It is noted that the convection velocity profile was consistent with the density profile in the case 3, however, was not consistent in the case 1. Further analyses are necessary to find the transport coefficients providing a best fit for both amplitude and phase difference and consistent with the density profile. The systematic comparison of the particle transport should be performed in future work.

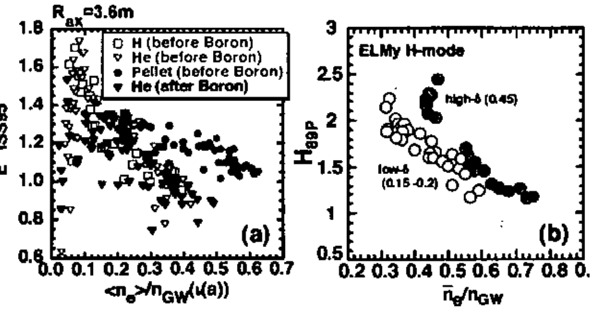

Fig. 1 Dependence of confinement enhancement factor on the density normalized by (equivalent) Greenwald density in (a) LHD and (b) JT-60U.

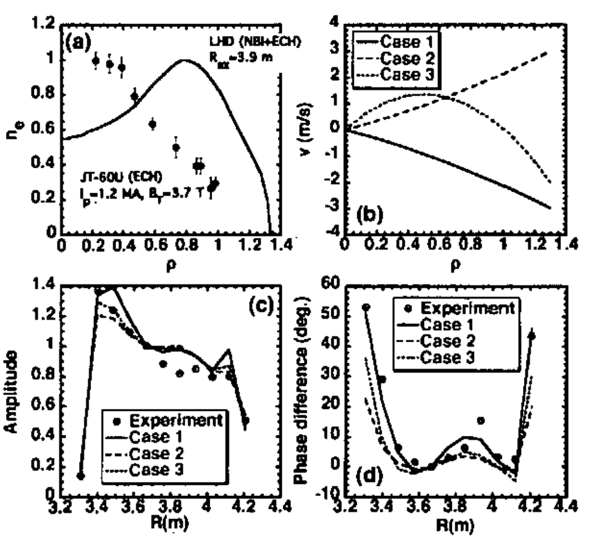

Fig. 2 (a) Density profiles normalized at maximum value in LHD (NBI+ECH) at $R_{ax}=3.9$ m (line) and JT-60U (ECH) (circles). (b) Convection velocity used for the calculations. (c) Amplitude and (d) phase difference for experiment (circles) and calculations (lines).

Reference
1) Takenaga, H., et al., JAERI-Review, **2003-029** (2003) 62.