§14. Theoretical Study on the Utilization of Radial Electric Field towards Increasing Temperature of LHD Plasmas

Murakami, S., Wakasa, A. (Kyoto Univ.),
Yokoyama, M., Osakabe, M., Takahashi, H.,
LHD Experiment Group

Experiments towards increasing plasma temperatures have been extensively progressed in accordance with the increased heating capability through ECH and NBI. The impacts of radial electric field, Er, for improving confinement in LHD, such as CERC[1)] (Core Electron-Root Confinement, electron-root) and high-ion temperature plasmas (ion-root)[2)], have been clarified through the experimental analyses[3)].

Such knowledge on the impacts of Er on improved confinement should also be examined and verified in recent high-temperature plasmas in LHD. This provides the firm basis for utilizing Er for further increasing plasma temperatures. This is the aim of this study.

It is of a great importance to accurately estimate the neoclassical (NC) diffusion, and then, Er based on the NC ambipolarity, especially in a low-collisionality regime where the NC diffusion properties are strongly influenced through the three-dimensionality of the magnetic configuration and Er. For this purpose, NC diffusion coefficient database, being created by the DCOM/NNW[4)] (Monte-Carlo/neural network approach), was extended to low-collisional regime in combination with GSRAKE[5)] code (bounce-averaged approach). This database has been incorporated into the NC module of the integrated transport code, TASK3D, so that fast and accurate calculations have become possible.

Present high-ion-temperature LHD plasmas are predicted to have the negative Er (ion-root) at peripheral region due to the almost equal ion temperature (Ti) and electron temperature (Te) and the density gradient. The ambipolar Er is predicted to be small negative at the core region where Ti>Te typically holds. Although it is small value of Er, it is essential to suppress the unfavorable ripple transport in high-Ti regime.

Along with the increased power of ECH, superposition of ECH onto the high-Ti plasmas was also extensively performed in FY2010 experiment. The further increase of Ti is aimed through the modification of Er through the increase of Te. In such a situation, a plasma with Ti~Te from core to the periphery was realized, reaching both 5 keV at the core. The ambipolar Er is predicted to have multiple roots in the core region with the negative value (ion-root solution) to be reduced in this particular situation. According to the Maxwell's construction[6)], the ion-root is the plausible solution. This modification of Er property is understood by that the ambipolar Er tends to become positive attributed to the increase of Te. However, the increase of Te seemed to be not enough to make the electron-root solution realized. Instead, decrease of the ion-root value (absolute value) of Er is interpreted to weaken the suppression of ripple diffusion. Slight reduction of the density value and/or slight increase of Te will be plausible scenario to make the electron-root realized so that the significant reduction of NC heat diffusivity is anticipated, as predicted[7)]. (According to the calculations described in Ref.7), about 0.5 keV increase both for ion and electron (at ρ~0.4) will provide the electron-root Er.)

Carbon pellet is injected in high-Ti plasma experiment. The impact of this pellet injection on Er property has also been examined. Before the injection, Te is larger than Ti at the peripheral region, to provide the electron-root Er there. On the other hand, Ti is almost equal to Te at core region, where small negative Er is predicted. After the injection, steepened density profile at peripheral region provides the large negative Er there, and at core region, the increase of Ti predicts the enhancement of the ion-root Er (having a larger absolute value). This enhancement of ion-root Er is favorable to suppress ripple diffusion.

Systematic comparison of the heat diffusivity between NC and power-balance, and predicted ambipolar Er and measured values (either by HIBP or CXS) are being performed. It will enhance the experimental verification on Er property and its impact on improved confinement, and then, the firm basis for predicting the efficient control and utilization of Er towards further higher-temperature LHD plasmas.

1) M.Yokoyama, H.Maassberg, et al., Nucl. Fusion 47 (2007) 1213.
2) K.Nagaoka, Y.Takeiri, et al., Fusion. Sci. Technol. 58 (2010) 46.
3) M.Yokoyama, A.Wakasa, S.Murakami, et al., Fusion Sci. Technol. 58 (2010) 269.
4) A.Wakasa, S.Murakami et al., Japanese Journal of Applied Physics, 46 (2007) 1157.
5) C.D.Beidler et al., Plasma Phys. Control. Fusion 36 (1994) 317.
6) K.Itoh, S.-I.Itoh and A.Fukuyama, "Transport and Structural Formation in Plasmas", IoP Bristol and Philadelphia (1999).
7) M.Yokoyama, S.Matsuoka et al., Contrib. Plasma Phys. 50 (2010) 586.