

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

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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, E_r , for improving confinement in LHD, such as CERC¹⁾ (Core Electron-Root Confinement, electron-root) and high-ion temperature plasmas (ion-root)²⁾, have been clarified through the experimental analyses³⁾.

Such knowledge on the impacts of E_r on improved confinement should also be examined and verified in recent high-temperature plasmas in LHD. This provides the firm basis for utilizing E_r 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, E_r 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 E_r . For this purpose, NC diffusion coefficient database, being created by the DCOM/NNW⁴⁾ (Monte-Carlo/neural network approach), was extended to low-collisional regime in combination with GSRAKE⁵⁾ 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 E_r (ion-root) at peripheral region due to the almost equal ion temperature (T_i) and electron temperature (T_e) and the density gradient. The ambipolar E_r is predicted to be small negative at the core region where $T_i > T_e$ typically holds. Although it is small value of E_r , it is essential to suppress the unfavorable ripple transport in high- T_i regime.

Along with the increased power of ECH, superposition of ECH onto the high- T_i plasmas was also extensively performed in FY2010 experiment. The further increase of T_i is aimed through the modification of E_r through the increase of T_e . In such a situation, a plasma with $T_i \sim T_e$ from core to the periphery was realized, reaching both 5 keV at the core. The ambipolar E_r 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 construction⁶⁾, the ion-root is the plausible solution. This

modification of E_r property is understood by that the ambipolar E_r tends to become positive attributed to the increase of T_e . However, the increase of T_e seemed to be not enough to make the electron-root solution realized. Instead, decrease of the ion-root value (absolute value) of E_r is interpreted to weaken the suppression of ripple diffusion. Slight reduction of the density value and/or slight increase of T_e will be plausible scenario to make the electron-root realized so that the significant reduction of NC heat diffusivity is anticipated, as predicted⁷⁾. (According to the calculations described in Ref.7), about 0.5 keV increase both for ion and electron (at $\rho \sim 0.4$) will provide the electron-root E_r .)

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

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

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