§5. Neoclassical Transport Analysis on High T_e Experimental Plasma in LHD

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In LHD, high electron temperature plasmas (T_e) have beeh observed with the ECH heating. These plasmas have the steep gradient of the electron internal transport barrier (eITB) and the large positive radial electric field (E_r) called the electron root with the steep shear at the plasma core region, thus are called Core Electron-Root Confinement (CERC) plasmas [1, 2]. In a CERC plasma, E_r plays a dominant role for its improvement of the confinement performance. It is widely known that the neoclassical transport in helical plasmas is not intrinsically ambipolar, and the E_r is determined by the ambipolar condition which is the constraint that the NC particle fluxes of the electron and ion balance to vanish the radial current, $\Gamma_\mathrm{e} = \Gamma_\mathrm{i}$, where the Γ_a denotes the NC particle flux and a is the particle species, $a =$ e, i. Since the E_r and its shear strongly affect both the NC and anomalous transport, determining the E_r profile precisely is one of the key issue in the transport studies.

Recently, it has been shown that the finite orbit width (FOW) effect of electrons becomes important for the neoclassical transport in high T_e helical plasmas such as CERC plasmas [3]. This is due to the fact that helically trapped particles can cause the large radial drift and change the neoclassical transport qualitatively. The steep T_e gradient also enhances the FOW effect in the CERC plasmas. To appropriately treat the electron FOW effect in the evaluation of the neoclassical transport, we have extended a numerical neoclassical transport code, FORTEC-3D, to be applicable to the electron.

Neoclassical transport analyses have been performed for a LHD discharge # 103619 using FORTEC-3D. The electron temeperatue at the core temporary increases as the ECH continues in this CERC plasma. In the plasma, a entirely flat T_e profile at the core ($\rho < 0.4$) is observed at $t = 0.8$ s. Then the T_e profile appears as a locally flat one approximately at $0.2 < \rho < 0.4$ with the eITB at $\rho < 0.2$ at $t = 0.9$ s, and finally it ends up with the eITB all over the core region of $\rho < 0.4$ at $t = 1.1$ s.

The radial electric field profiles obtained by FORTEC-3D are shown in Fig. 1. It is shown that the large positive radial electric field is spontaneously formed along with the increase in the electron temperature. The neoclassical heat diffusivities, χ_e of the CERC plasma are shown in Fig. 2. The experimental χ_e are estimated from the input power of ECH heating and also shown in this figure. It is clearly shown that the neoclassical χ_e rather remains low level even when T_e becomes high at $t = 0.9$ and 1.1 s. We can see that the NC heat diffusivity *does not* show the so-called $1/\nu$ scaling with the large electron-root E_r in the CERC plasma, where ν is the collisionality. This is due to the formation of the large electron-root E_r during the eITB formation shown in Fig. 1. At the same time, experimental estimated heat diffusivity is reduced by the radial electric field. Therefore, it can be concluded that the improved confinement in the CERC plasma can be accomplished by automatically avoiding the $1/\nu$ degrading of the NC transport and reducing the turbulent transport with the spontaneous formation of the large electron-root E_r along with the increase in T_e

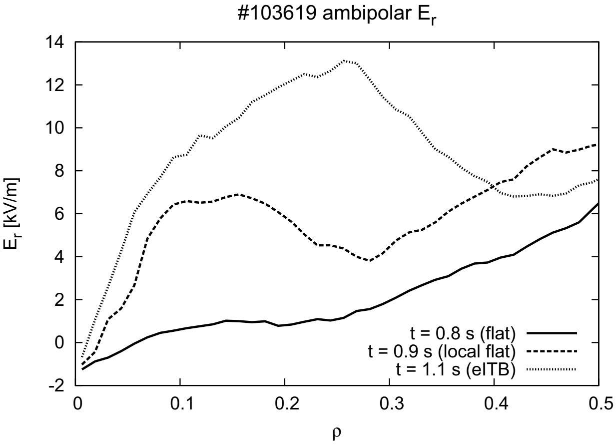

Fig. 1: The ambipolar radial electric field profiles for the LHD CERC plasma obtained by FORTEC-3D. Each E_r profile shows a value at the steady state.

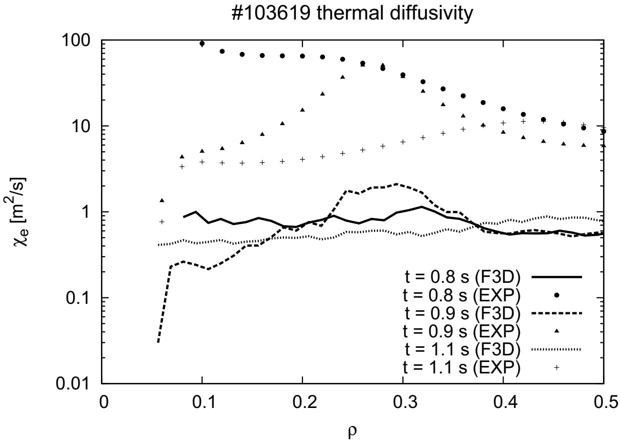

Fig. 2: Radial profiles of the heat diffusivity evaluated by FORTEC-3D code for the CERC plasma. Circles with corresponding colors are experimental estimations, respectively.

1) Ida, K., Phys. Rev. Lett. **91** (2003) 085003.

2) Yokoyama, M., Fus. Sci. Technol. **50**, (2006) 327.

3) Matsuoka, S., Phys. Plasmas **18**, (2011) 032511.