§7. V&V on Local and Global Neoclassical Transport Codes for Helical Plasmas

Satake, S., Yokoyama, Y., Huang, B. (SOKENDAI), Matsuoka, S. (JAEA)

For the transport analysis in helical plasmas, neoclassical transport plays an important role because neoclassical flux in helical plasma can be comparable to anomalous transport. Since it strongly depends on the radial electric field, self-consistent treatment of neoclassical transport calculation and determination of ambipolar radial electric field are the main subjects.

We had constructed global FORTEC-3D code, which solves 5-dimension drift-kinetic equation including the finite radial drift effect, or the finite-orbit-width (FOW) effect, to improve the qualitative reliability of neoclassical simulation. On the other hand, conventional calculations such as GSRAKE and DKES codes adopt the local approximation, in which the FOW effect by the magnetic drift is completely neglected (zero-magnetic-drift (ZMD) model) and incompressibility of $E \times B$ flow is assumed. It has been revealed that the neoclassical flux from global and local codes sometimes show large discrepancy. However the reason of this large difference had not been fully studied. Recently, we have developed a new local drift-kinetic model, zero-orbit-width (ZOW) model[1)], in which only the radial component of magnetic drift is neglected but its tangential component to the flux surfaces and the $E \times B$ compressibility are kept as in FOW model. From parameter-survey studies[1, 2)] it is found that the main difference between local and global calculations when $E_r \sim 0$ is caused by the cancellation of poloidal precession drift, $\omega_\theta = (\mathbf{v}_{E\times B} + \mathbf{v}_B) \cdot \nabla\theta \simeq 0$, where the $\mathbf{v}_B \cdot \nabla\theta$ term is considered only in FOW and ZOW models. Since the magnetic drift velocity $\mathbf{v}_B$ depends on the particle energy but $\mathbf{v}_{E\times B}$ is common for all the particles, strong resonance $\omega_\theta \simeq 0$ happens in ZMD model and it results in overestimation of radial neoclassical transport.

The impact of the differences in the drift-kinetic equation models on the transport analysis of real experiments have been benchmarked in LHD and TJ-II discharges[3)]. The ambipolar-E_r profile is estimated by finding the condition $\Gamma_i = \Gamma_e$ in the simulations, as shown in Fig. 1. Because of the different dependence of $\Gamma_{i.,e}$ on E_r among the simulation models, the ambipolar condition varies. Around the electron-root, the difference of ambipolar-E_r among three codes are relatively small and they agree well with the measurement by HIBP. However, as shown in Fig. 2, the electron (and also ion) enegy flux Q_e at the ambipolar-E_r differs as large as factor 2 between global and local codes. The same tendency has been found in the transport analysis of a TJ-II discharge. The energy flux was also evaluated from the measurement and heating deposition. It is found that neoclassical Q_e is about the same magnitude as the measured one in TJ-II and $\sim 1/4$ in LHD electron-root plasmas. Since $Q_{anom} \simeq Q_{total} - Q_{neo}$ and $Q_{anom} \sim Q_{neo}$, improvement of the quantitative accuracy in neoclassical transport is also important for the estimation of the anomalous transport level.

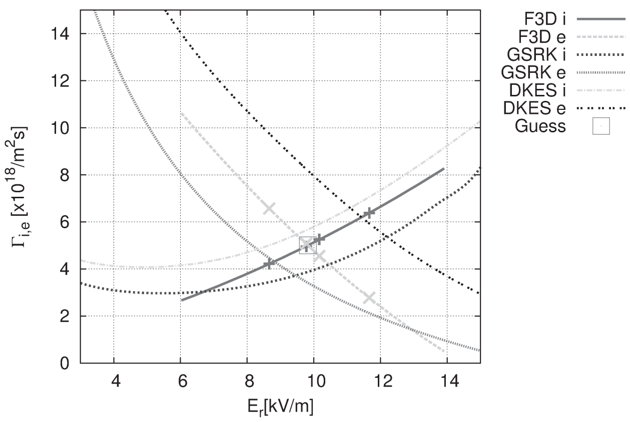

Fig. 1: Particle flux $\Gamma_{i,e}$ from several simulatoins around an electron-root on $r = 0.35a$ surface in LHD plasma

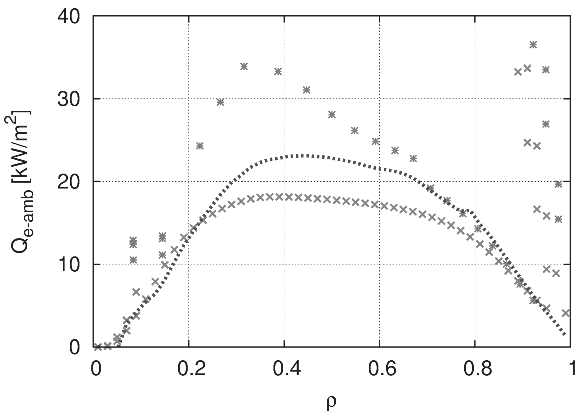

Fig. 2: Electron enegy flux Q_e from FORTEC-3D(blue), DKES(red), and GSRAKE(blue) codes at the electron-root in LHD plasma

1) S. Matsuoka et al., Phys, Plasmas **22**, 072511 (2015).

2) B. Huang et al., to be submited to Phys, Plasmas.

3) S. Satake et al., *"Verification and Validation of Neoclassical Transport Codes for Heliotron / Stellarator Devices"*, 20th International Sltellarator-Heriotron Workshop, S1-I5 (invited talk).