§26. Neoclassical Transport in the Boundary Region of the Quasi-Axisymmetric Configurations

Nishimura, S., Okamura, S., Kanno, R., Suzuki, C., Isobe, M.

One of the important motivations of the quasi-axisymmetric (QA) configuration having small helical and bumpy ripples as a candidate for post-CHS (CHS-qa, R=1.5m, a~0.4m, $B \leqq 1.5$T, N=2)[1-2] is originated in considerations related to the radial electric fields in conventional helical devices. The radial electric fields had been explained mainly by the ambipolarity condition of non ambipolar ripple diffusion fluxes that originate in the 3-dimensional asymmetry of the magnetic field configurations. For generating a strong radial electric field spontaneously not due to the neoclassical ripple effects but due to the other effects discussed in relation to edge transport barriers in tokamaks[3], some kinds of symmetry in magnetic field configurations, which reduce the ripple diffusion fluxes, are required. We regard the concept of quasi-symmetry as important for this flexibility of radial electric fields in helical systems. Although the 'quasi-symmetry' is the toroidal or helical symmetry of magnetic field strength in the Boozer coordinates and is not a geometric symmetry, the neoclassical characteristics of the plasmas based on the drift kinetics is considered to be approximately identical to that of axisymmetric tori (intrinsically ambipolar).

Therefore, to evaluate the effect of the residual bumpy and helical ripples is important in the optimization of the QA configuration. To evaluate the reduction of the non ambipolar ripple diffusion fluxes, we adopted DKES (Drift Kinetic Equation Solver) codes[4]. However, this kind of neoclassical calculation codes based on the drift kinetic and/or Monte Carlo method use pitch angle scattering operators that do not express the inter-species momentum conservation which is required for the calculation of friction force. Therefore, the friction driven ambipolar diffusion fluxes (banana-plateau, Pfirsch-Schlueter, classical) cannot be calculated correctly though the friction driven fluxes and the viscosity driven non-ambipolar ripple diffusion fluxes cannot be separated. This problem is a future theme. We present here the comparison of the mono-energetic "diffusion coefficient" $\Gamma_{code}(11)$, and the energy integrated "diffusion coefficient" L_{11} given by DKES for CHS, CHS-qa(2b32 configuration) and an imaginary "equivalent" tokamak that has no non-axisymmetric magnetic field spectrum components B_{mn}(n≠0) in the Boozer coordinates and has the axisymmetric components B_{mn}(n=0) and the rotational transform of CHS-qa. Fig.1 shows mono-energetic diffusion coefficients and Fig.2 shows the energy integrated diffusion coefficients at ρ=0.9 of CHS and CHS-qa. In the operation regime of CHS and CHS-qa ($1/\nu$ ~ plateau), the diffusion coefficients of CHS-qa is reduced by 10^{-3}~10^{-2} compared with that of CHS in the case of E_r~ 0V/m. This reduction of the ripple diffusion is consistent to a rough estimation using a semi-analytic formula based on a single helicity approximation[5]. The dependence of these coefficients of CHS-qa on the radial electric field and the collision frequency is also reduced compared with CHS, and electron diffusion coefficients of CHS-qa in a collisional regime is comparable to that of the tokamak. It indicates that the effect of the friction force mentioned above is not negligible compared with the viscosity effect in the neoclassical calculation.

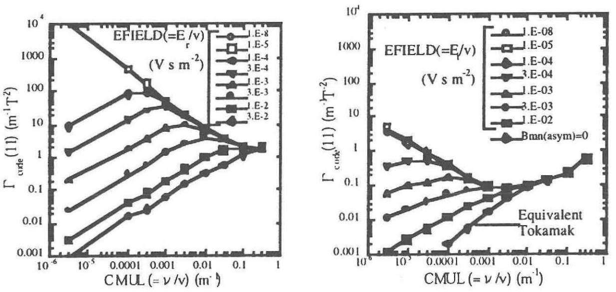

Fig.1 The mono-energetic diffusion coefficients at ρ=0.9 of CHS (left) and CHS-qa(2b32) (right). The diffusion coefficients decrease monotonically with increasing the radial electric field

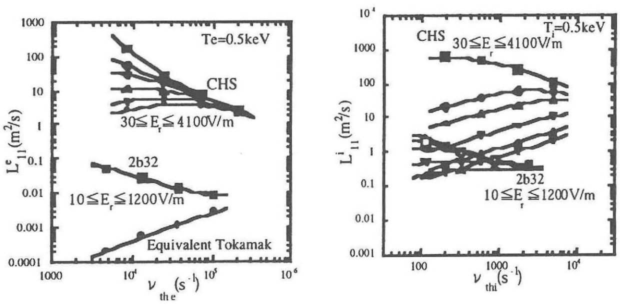

Fig.2 The energy integrated diffusion coefficients of electron (left) and ion (right) at ρ=0.9 of CHS and CHS-qa.

Reference

1) Okamura,S., Murakami,S., Shimizu,A., et al.,J.Plasma Fusion Res.SERIES **3**, (2000)73

2) Suzuki,C., et al., in 11th International Toki Conference

3) ITER Physics Expert Group, Nucl.Fusion **39**, (1999)

4) Hirshman,S.P., et al.; Phys.Fluids **29**, (1986)2951
van Rij,W.I., Hirshman,S.P., Phys.Fluids **B1**, (1989)563

5) Shaing,K.C., Phys.Fluids **27**, (1984)1567