§27. Neoclassical Transport Calculation in an Imaginary Axisymmetric Limit in CHS-qa

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To demonstrate the validity and effectiveness of a newly developed neoclassical transport calculation method[1], the numerical examples in an imaginary axisymmetric limit in CHS-qa (so-called the "2b32" configuration)[2]are presented here. One of the important aims of recently proposed quasi-symmetric configurations is to release the radial electric fields and the plasma flows from the neoclassical ambipolar constraint similarly to exactly symmetric configurations. The magnetic field strength on the flux surfaces can be expressed by the Fourier expansion $B=\Sigma\ B_{mn}\cos(m\ \theta\ -nN\ \zeta\ )$ in the flux coordinates (m: poloidal mode, n: toroidal mode per toroidal period). In the imaginary axisymmetric limit in which the non-axisymmetric components ($n\neq 0$) of this Fourier expansion are artificially set to be zero, the results of the thermodynamic fluxes should coincide with the theory of axisymmetric tori[3], since neoclassical calculations based on the drift approximation need only this magnetic field expressed in the flux coordinates and do not need the geometric shapes of magnetic surfaces. Thus neoclassical calculation methods to evaluate the quality of the quasi-symmetry should unify the theories for both of non-symmetric and symmetric configurations and in various collisionality regimes.

Figure 1 shows the mono-energetic transport coefficients D_{11}(radial transports), D_{13}(bootstrap flow and Ware pinch) and D_{33} (parallel viscosity) given by DKES(Drift Kinetic Equation Solver) code at the minor radial position r/a =0.5 of CHS-qa. In the axisymmetric limit, dependence of the coefficients on the radial electric fields almost disappears. These coefficients are used to express the viscosity effects in the fluids momentum balance equations. And the parallel flows and the radial transports are determined by these momentum balance equations satisfying the collisional momentum conservation. Figure 2 shows the calculation results of the radial particle diffusion fluxes in a fully ionized hydrogen plasma. The calculation using only D_{11}, following the conventional method for low collision frequency regimes in non-symmetric configurations, cannot obtain the well-known intrinsic ambipolarity in symmetric limits. By adding other terms due to the collisional momentum conservation given by the new method, the ambipolar condition is obtained automatically. Easiness in expanding to multi-ion-species problems is another feature of this new method based on the moment approach[3]. Figure 3 shows the radial particle diffusion fluxes in a fully ionized hydrogen plasma having fully ionized helium of 10% as an impurity. The ambipolarity condition is automatically attained. The strong dependence of the diffusion of H^+ and He^{2+} on the density gradient ratio indicates the well-known impurity accumulation minimizing the parallel friction forces between bulk ions and impurity ions. The quasi-steady state condition of the density profile is attained at the condition of $(\partial \ln n_{He2+}/\partial\rho)/(\partial \ln n_{H+}/\partial\rho)=2$.

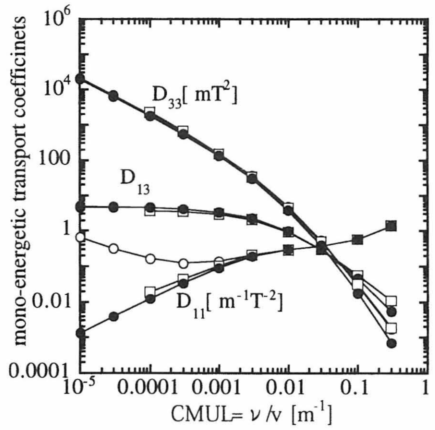

Fig.1 mono-energetic transport coefficients at r/a=0.5. Open circles ○ indicate the case without radial electric fields (E_r=0) and open squares □ indicate the case with the radial electric field of E_r/v =0.01T. The axisymmetric limit is indicated by closed circles ●.

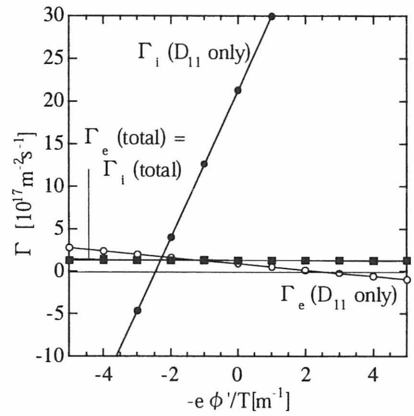

Fig.2 The dependence of the particle diffusion fluxes on the radial electric field in the axisymmetric limit calculated with the assumed electron density and temperatures of $n_e=5\times 10^{18}m^{-3}$ and $T_e=T_i$=1keV.

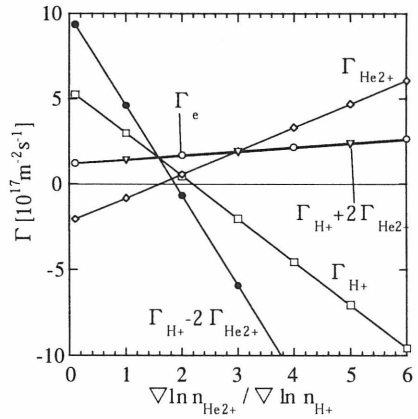

Fig.3 The particle diffusion fluxes in a plasma having fully ionized helium as an impurity of 10% with assumed electron density and temperatures of $n_e=5\times 10^{18}m^{-3}$ and $T_e=T_i$=1keV.

References

[1] Sugama,H. and Nishimura,S., NIFS-732, in this Report
[2] Okamura,S., et al., Nucl.Fusion 41,1865(2001)
[3] Hirshman,S.P., Sigmar,D.J., Nucl.Fusion 21,1079(1981)