§8. Use of DKES Code II: Use of S-N Method

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After the calculation of mono-energy transport coefficients by using the DKES code [1], they are used to obtain the neoclassical fluxes, flows, viscosities, etc. For this purpose, we use the method by Sugama and Nishimura [2] (S-N) which gives the linear relations between the fluxes and the forces. The main progress of [2] is the consideration of the momentum conservation of the collision term, in addition to the particle number and energy conservations. The conventional method ensures only the last two conservations. As a result, higher order correction to the cross-field fluxes is achieved, and simultaneously the parallel flows, viscosities, can be obtained self-consistently.

The corrections will be visible well when the cross-field fluxes are reduced, which occurs in the long mean path regime in symmetric magnetic field configurations. Thus, we consider a tokamak configuration obtained by the VMEC [3]. A surface in the banana regime is chosen. To obtain the mono-energy coefficients, Fourier and Legendre mode numbers, $(m_{max},n_{max},l_{max})=(16,12,100)$ are used.

In Fig.1, the particle fluxes for the electron (circles) and ion (squires) are shown as a function of electric field. The solid and dashed lines correspond to results by the S-N method and the conventional method (only $\mathcal{L}$ matrix is considered in [2]) respectively. In the S-N case, as a result of the momentum conservation, the ion and electron fluxes almost coincide, independent of the electric field. This is the well-known intrinsic ambipolarity. On the other hand, in the conventional case, there exists the intersection of the electron and ion fluxes, and the ambipolar electric field is possibly determined as in the asymmetric systems, which is physically invalid.

It can be seen that the ion flux in the S-N case is slightly changed at large $|E_s|$. To see the reason, in Fig.2, $-(e_a/\langle B^2\rangle)[N_a(K)/M_a(k)]$ and $-(e_a/\langle B^2\rangle)[L_a(K)/N_a(k)]$ with a=ion are plotted as a function of $K=(v/v_{th})^2$ by closed and open circles respectively, where $N_a(K)$, $M_a(k)$, $L_a(k)$ are functions of mono-energy coefficients defined in Ref.[2]. These should be equal to the constant G^{BS} shown by dashed line in the symmetric configurations, as in Eq.(D4) of Ref.[2]. If these relations were satisfied, it can be analytically confirmed in the Appendix C of [2] that the intrinsic ambipolarity is automatic. The different points on a fixed K correspond to the different E_s values, and there is some deviation from the constant G^{BS}, in particular at the small K and large $|E_s|$. As expected, the errors of the mono-energy coefficients are worse for these points. The deviation seems to be large, but in the energy integral, its contribution is not so large, as in Fig.1.

In this report, the intrinsic ambipolarity is confirmed numerically by the S-N method, at some level. This assures that the coding on the fluxes-forces relation is working, and the DKES code is ready for the realistic applications.

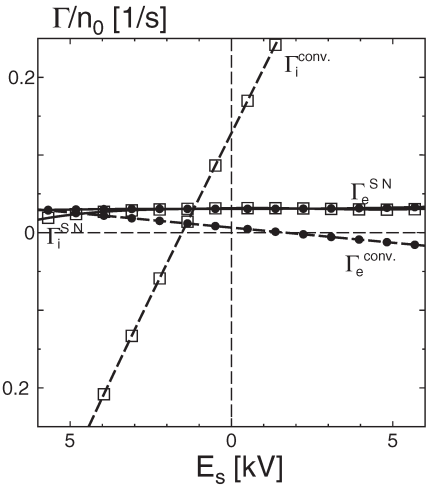

Figure 1: The particle fluxes by the conventional (dashed lines) and S-N method (solid lines) for ion (squares) and electron (circles).

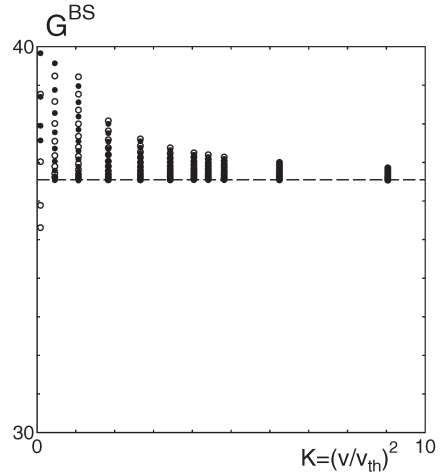

Figure 2: G^{BS} factor and its counterparts from the mono-energy coefficients

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2) H.Sugama and S.Nishimura, Phys. Plasmas **9**, 4637 (2002)
3) S.P.Hirshman, Phys. Fluids **26**, 3553 (1983)