§6. How to Calculate the Neoclassical Viscosity, Diffusion, and Current Coefficients in General Toroidal Plasmas

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A novel method to obtain the full neoclassical transport matrix for general toroidal plasmas by using the solution of the linearized drift kinetic equation with the pitch-angle-scattering collision operator is shown.[1] In this method, the neoclassical coefficients for both poloidal and toroidal viscosities in toroidal helical systems can be obtained, and the neoclassical transport coefficients for the radial particle and heat fluxes and the bootstrap current with the non-diagonal coupling between unlike-species particles are derived from combining the viscosity-flow relations, the friction-flow relations, and the parallel momentum balance equations. Since the collisional momentum conservation is properly retained, the well-known intrinsic ambipolar condition of the neoclassical particle fluxes in symmetric systems is recovered. Thus, these resultant neoclassical diffusion and viscosity coefficients are applicable to evaluating accurately how the neoclassical transport in quasi-symmetric toroidal systems deviates from that in exactly-symmetric systems.

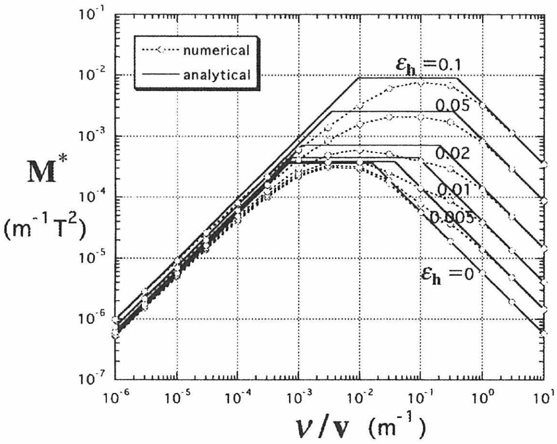

Fig.1. The monoenergetic parallel viscosity coefficient M^* as a function of ν/v.

Figures 1–3 shows the monoenergetic parallel viscosity coefficient, diffusion coefficient, and the geometrical factor for the bootstrap current, respectively, which are plotted as a function of the ratio between the collision frequency ν and the particle velocity v for the magngetic field strength given by $B = B_0[1 - \epsilon_t \cos\theta_B - \epsilon_h \cos(l\theta_B - n\zeta_B)]$, with $B_0 = 1\ T$, $\epsilon_t = 0.1$, $0 \leq \epsilon_h \leq 0.1$, $l = 2$, and $n = 10$. In Figs. 1-3, dotted curves with open circles and solid lines represent results from combining our method with numerical output of the DKES[2] and those from analytical formulas for limiting collision frequency regimes, respectively, which show a good agreement and validity of our method. Figure 4 plots the poloidal and toroidal viscosity coefficients obtained by using the numerical results in Figs. 1-3. We see that increase of these coefficients due to the helical ripple becomes clearer for lower collisionality.

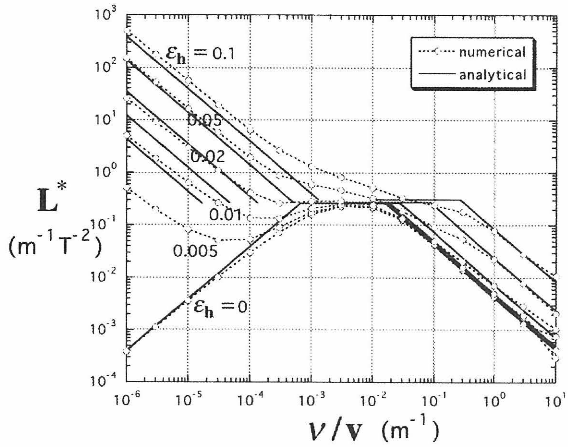

Fig.2. The monoenergetic diffusion coefficient L^* as a function of ν/v.

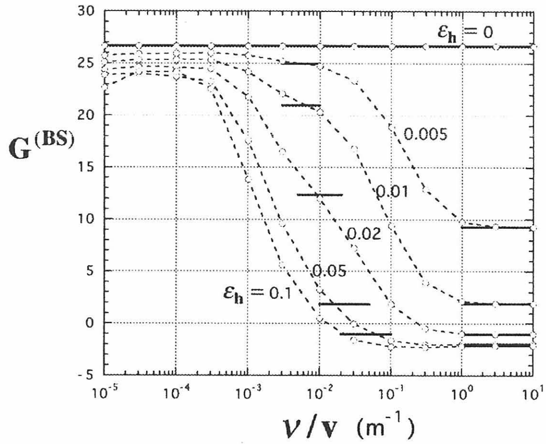

Fig.3. The geometrical factor for the bootstrap current $G^{(BS)}$ as a function of ν/v.

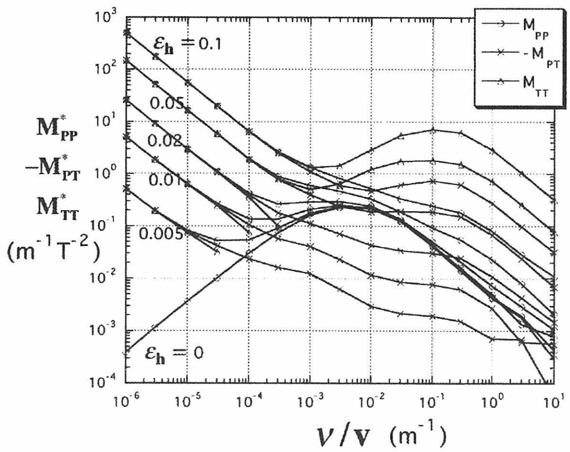

Fig.4. The monoenergetic poloidal and toroidal viscosity coefficients M^*_{PP}, M^*_{PT}, and M^*_{TT} as a function of ν/v.

References
1) Sugama, H., and Nishimura, S., NIFS-732.
2) van Rij, W. I. and Hirshman, S. P., Phys. Fluids B **1** (1989) 563.