§14. Neoclassical Viscosities in Helical Devices with Low Aspect Ratios I: NCSX

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Previously reported benchmarking examples for the analytical formulas of neoclassical viscosities(1) were made implicitly assuming applications in a future integrated simulation system for the LHD (Large Helical Device)(2). Therefore the toroidal period numbers assumed there were mainly N=10. To clarify the applicability of the analytical methods even for configurations with extremely low toroidal period numbers (required for low aspect ratios), we show here recent benchmarking examples in NCSX (National Compact Stellarator Experiment)(3) with N=3 and QPS (Quasi-poloidal Stellarator)(4) with N=2.

Firstly we present results in the NCSX in this page. It is a quasi-axisymmetric (QA) toroidal system with N=3, R_0=1.4m, a=0.32m, and $B_0\leq$2T. Figure 1 shows the magnetic field strength on the flux surface in a standard configuration (NCSX-m50) with a finite beta of β=4% and a finite toroidal current of I_{p}=178 kA. The minor radial position in the figure is that with normalized toroidal flux of $(\psi/\psi_{\mathrm{edge}})^{1/2}$=0.51 (corresponding to $r\cong$0.165m). In the technical viewpoint of the analytical calculation of the mono-energetic viscosity coefficients N^* (non-diagonal term corresponding to driving forces of bootstrap currents and the Ware pinch) and L^* (diagonal term for radial diffusions) defined in Refs.[1,5], an important issue that must be investigated in this type of magnetic configuration is the $1/\nu^{1/2}$ component in L^*. It is caused by the ripple-trapped/untrapped boundary layer at $\kappa^2\approx1$ in the velocity space(6), and can be seen only in configurations with small toroidal period numbers and small ripple amplitudes giving a strong reduction of well-known $1/\nu$ diffusions(7). Figure 2 shows these viscosity coefficients obtained by the analytical(1,7) and the numerical(5) methods. Because of the strongly reduced $1/\nu$ diffusion, a previously reported boundary layer effect on N^*, which gives a dependence of this coefficient on the radial electric field(1), is not so important as shown in Fig.2(a). In contrast to it, the boundary layer effect in L^* can be seen in Fig.2(b), where we compared the pure $1/\nu$ component given by the NEO code(8) with that including the $1/\nu^{1/2}$ component given by an analytical formula(6,7). In spite of the complex magnetic field spectra, this simple formula is applicable because of a weak dependence of the $1/\nu^{1/2}$ component on the ripple amplitude δ_{eff}.

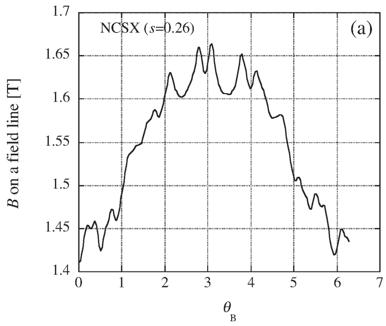

Fig.1 Magnetic field strength at $(\psi/\psi_{\mathrm{edge}})^{1/2}$=0.51

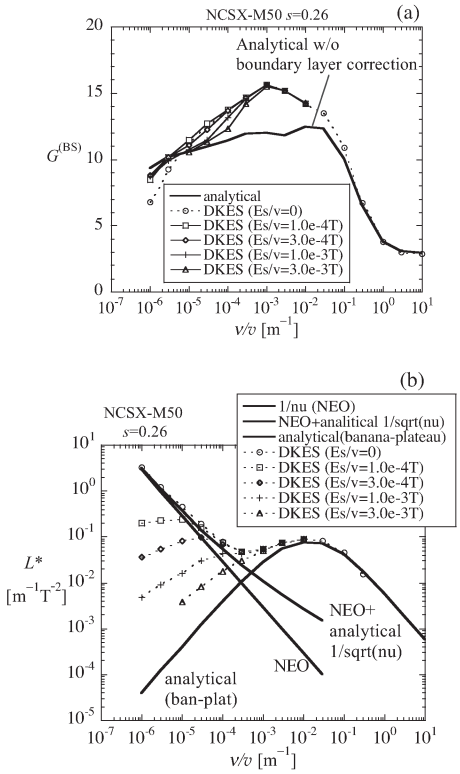

Fig.2 Mono-energetic viscosity coefficients given by the analytical methods (solid curves) and by the numerical method in the 3-D phase space (DKES) (open symbols). (a) the geometrical factor $G^{(\mathrm{BS})}\equiv-\langle B^2\rangle N^*/M^*$, (b) components of the diagonal diffusion L^*.

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