Simulation studies on neoclassical viscosity in 3-dimensional magnetic configurations

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Control of the toroidal rotation is an important issue in tokamaks in order to improve the stability of the confined plasmas. Recent studies have shown that the non-axisymmetry as small as $\delta B/B_0 \sim 10^{-4}$ can induce significant damping in toroidal rotation. To give a precise prediction of the toroidal rotation damping by small perturbation, a new simulation to evaluate neoclassical toroidal viscosity (NTV) is developed using the δf Monte Carlo method[1]. It solves the guiding-center distribution function in non-axisymmetric plasmas according to the drift-kinetic equation, and evaluate the NTV directly from numerical solution of the perturbed distribution function δf.

In the presentation, we report some recent benchmark results of the simulation as follows. Basic properties of NTV such as dependence of the viscosity on collision frequency and perturbation field strength are investigated in a multi-helicity perturbation field models and compared with a bounce averaged asymptotic formulae for the $1/\nu$ and SuperBanana-Plateau (SPB) regimes by Shaing[2] and a combined analytic formula by Park[3]. In the zero-$\mathbf{E}\times\mathbf{B}$ rotation limit, it is found that clear $1/\nu$ and SPB dependences cannot be seen in the δf simulation, while very good agreement is found between the δf simulation and the combined analytic formula, which successfully takes account of the particles' energy dependence on the resonant condition between the precession drift and collisional detrapping frequencies[4]. It is found that the asymptotic limit theories for the $1/\nu$ and SPB regimes tends to overestimate the NTV. The well-known δB^2-dependence of NTV is reproduced in the Monte Carlo simulation.

The relation between the neoclassical viscosity and rotation is also important to understand and control the plasma confinement in helical devices, in which ambipolar radial electric field evolves so as to maintain the charge neutrality and the large poloidal $\mathbf{E}\times\mathbf{B}$ rotation serves to reduce the neoclassical flux. Dependence of the poloidal viscosity on the $\mathbf{E}\times\mathbf{B}$ rotation and the magnetic configurations have been studied in LHD experiments using biasing electrode in recent campaigns[5]. In the presentation, we will analyze the neoclassical poloidal viscosity in LHD plasmas using the simulation.

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