Monte Carlo computation of neoclassical poloidal and toroidal viscosity coefficients in helical-axis heliotrons

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Recently developed Monte Carlo based code [1] is applied to calculate the neoclassical transport for a helical-axis heliotron [2]. This code can predict not only the parallel, but also the poloidal and toroidal viscosities in the framework of the moment-equation approach [3]. A particular feature of our Monte Carlo code is that the required mono-energetic diffusion L^* and viscosity coefficients M^* and N^* are obtained by the Einstein-Helfand relation, which has been employed in molecular dynamics simulations. Note that L^*, M^*, and N^* can be determined for arbitrary collision frequency with radial electric field. By using this code, we can also determine the poloidal and toroidal viscosity coefficients as well as the nondiagonal coupling, which are denoted by M^*_{PP}, M^*_{TT}, and M^*_{PT}. These viscosity coefficients characterize the effect of the magnetic field ripple on the toroidal and poloidal flows tangent to flux surfaces for three dimensional MHD equilibria.

The validity of our Monte Carlo code has so far been demonstrated [1] for simple $l = 2$ heliotrons. Here, we report numerical results for $l = 1$ helical-axis heliotrons, which have the toroidal mirror harmonics of the magnetic field spectrum when represented in the Boozer coordinates; this harmonics is often referred to as bumpiness. The effect of bumpiness on the confinement properties has been studied in the Heliotron J device [2], both experimentally and theoretically. In the previous numerical studies, it has been shown that the bumpiness that has sign opposite to the helicity can reduce the $1/\nu$ ripple diffusion [2], and can also change the magnitude and the sign of the bootstrap current [4]. In the present paper, we investigate the neoclassical poloidal and toroidal viscosities because of their relevance to momentum transport properties in such devices. To illustrate the role of bumpiness on the neoclassical viscosity, we retain only three dominant magnetic field ripples in the $l = 1$ heliotron model. We evaluate the poloidal and toroidal viscosity coefficients M^*_{PP}, M^*_{PT}, and M^*_{TT} for this model. The dependence of these coefficients on the radial electric field will also be reported. In the relatively low collisionality regime, the radial electric field is of importance owing to its crucial influence on the toroidal and poloidal viscosities.

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