Enhancement of Residual Zonal Flows in Helical Systems with Equilibrium Radial Electric Fields

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We have been investigating the interaction between zonal flows and turbulence in helical systems such as heliotrons and stellarators based on gyrokinetic theory and simulation [1-5]. In helical systems, the equilibrium radial electric field *Er* determined from the ambipolar particle flux condition generates the macroscopic ***E***×***B*** rotation. This ***E***×***B*** rotation, which is distinguished from the microscopic sheared ***E***×***B*** zonal flows, is expected to further enhance the residual zonal-flow level as pointed out by Mynick and Boozer [6] who used the action-angle formalism to treat poloidally closed ***E***×***B*** drift orbits of helical-ripple-trapped particles. We have taken account of the closed and unclosed ***E***×***B*** drift orbits, the latter of which can transit to the toroidally-trapped orbits with some probability, and derived the formulas for collisionless zonal-flow responses [5]. Consequently, the zonal-flow responses are predicted to be raised either by neoclassical optimization of the helical geometry lowering the radial drift or by strengthening *Er* to boost the poloidal rotation. In order to confirm the prediction, the time evolution of the zonal-flow potential is solved by using the gyrokinetic Vlasov (GKV) code, of which the simulation domain is extended from a flux tube to a poloidally-global region [4]. Figure 1 shows results for the cases of $M_p = 0$ ($E_r = 0$) and $M_p = 0.3$ where M_p represents the poloidal Mach number of the ***E***×***B*** drift velocity. Here, the model geometry of the inward-shifted LHD configuration is used. The enhancement of the residual zonal-flow level due to *Er* is clearly verified. We find that this enhancement due to *Er* is more evident for the inward-shifted case than for the standard LHD. The *Er* effect appears through *Mp*. When the magnitude of *Er* and the magnetic geometry are fixed, higher zonal-flow responses are obtained by using ions with a heavier mass, which increases *Mp*, and accordingly the resultant turbulent transport is expected to show a more favorable ion-mass dependence than the conventional gyro-Bohm scaling.

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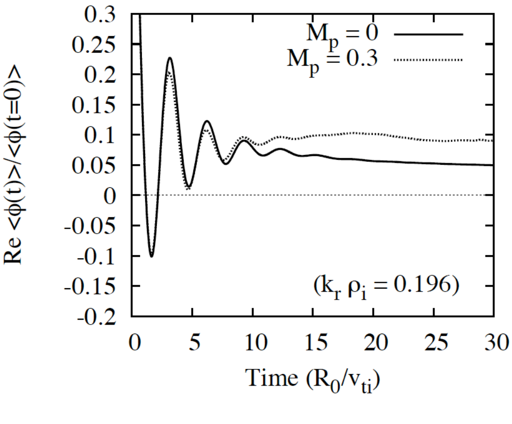

Fig.1 Time evolution of the zonal-flow potential