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Extended Bounce-Kinetic Model for Trapped Particle Mode Turbulence

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Bounce-kinetic model based on the modern nonlinear bounce-kinetic equations[1] has been used for gKPSP[2] gyrokinetic simulations and produced useful and promising results[3]. However, magnetically trapped particles were treated as deeply trapped in that TEM and ITG simulation. This paper reports on an extension including the barely trapped particles. This will allow simulations addressing the precession reversed particles'effect, reversed shear plasmas, and more precise neoclassical polarization shielding[4]. Modern bounce-kinetic equation advances the distribution function $F(\bar{Y_1}, \bar{Y_2}, \bar{\mu}, \bar{J})$ according to

$$\frac{\partial}{\partial t}F + \frac{d\bar{Y_1}}{dt}\frac{\partial F}{\partial \bar{Y_1}} + \frac{d\bar{Y_2}}{dt}\frac{\partial F}{\partial \bar{Y_2}} = 0tag1 \quad (1)$$

where $\bar{Y_1}$ and $\bar{Y_2}$ are bounce-averaged magnetic flux coordinates of gyrocenter, $\bar{\mu}$ and $\bar{J}$ are the first and the second adiabatic invariant respectively. With the total bounce-center Hamiltonian including the perturbation $\langle H \rangle$, $\frac{d\bar{Y_1}}{dt} = \frac{c}{q}\frac{\partial \langle H \rangle}{\partial \bar{Y_2}}$ and $\frac{d\bar{Y_2}}{dt} = -\frac{c}{q}\frac{\partial \langle H \rangle}{\partial \bar{Y_1}}$ describe the motion of bounce-centers. While the expression of $\bar{J}$ in terms of particle's energy and pitch angle is well-known in terms of elliptic functions[5], their inversion is necessary to express Maxwellian distribution in terms of the action-angle variables. This is straightforward for deeply trapped particles. In this work, we find analytic expressions for barely trapped particles in terms of Lambert function. The associated Poisson equation in terms of F is derived via pull-back transformation from the bounce-center coordinates to gyro-center coordinates [4]. The neoclassical polarization density which quantifies the Rosenbluth-Hinton residual zonal flow level[6] is also calculated. Initial simulation results using this scheme will be reported.

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