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A Fully-Neoclassical Finite-Orbit-Width Version of the CQL3D Fokker-Planck Code

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The finite-difference bounce-average Fokker-Planck (FP) code CQL3D [R.W. Harvey and M. McCoy, "The CQL3D Fokker Planck Code"] has been upgraded to include the Finite-Orbit-Width (FOW) effects. This is achieved by transforming the FP equation written in canonical action variables to another set of Constant-Of-Motion (COM) coordinates. A distinctive feature of our approach from that used by other authors is the selection of the major radius at the equatorial plane as one of the COM coordinates, i.e., we adopt I = (R0, u0, pitch0) as the COM coordinates. Here, R0 is the major radius coordinate along the equatorial plane (the midplane of tokamak, in case of up-down symmetrical equilibrium). For each given R0 point, the value of particle speed (momentum-per-mass) u0 and value of the pitch-angle pitch0 at this point determine a unique orbit. The banana regime neoclassical radial transport appears naturally in the FOW version by averaging the local collision coefficients along guiding center orbits, with a proper transformation matrix from local (R, Z) coordinates to the midplane computational coordinates, where the FP equation is solved. In a similar way, the local quasilinear RF diffusion terms give rise to additional radial transport of orbits. The FOW modifications are implemented in the formulation of the neutral beam source, collision operator, RF quasilinear diffusion operator, and in synthetic particle diagnostics. The CQL3D-FOW version is applied to simulation of ion heating in NSTX plasma. It is demonstrated that it can describe the physics of transport phenomena in plasma with auxiliary heating, in particular, the enhancement of the radial transport of fast ions by RF heating and the occurrence of the bootstrap current. Because of the bounce-averaging on the FPE, the results are obtained in a relatively short computational time. A typical run time is 30 min using 140 MPI cores. Due to an implicit solver, calculations with a large time step (tested up to dt = 0.5 sec) remain stable.

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