Development of 5D drift kinetic equation solver with momentum conserving collisional operator in the toroidal plasmas

S. Murakami, S. Hasegawa and Y. Moriya

Department of Nuclear Engineering, Kyoto University, Nishikyo, Kyoto 615-8530, Japan

murakami@nucleng.kyoto-u.ac.jp

The conservation of the momentum during particle collisions is an important issue in studying the electron cyclotron current drive (ECCD), the neoclassical transport and etc. In this study the velocity dependent model is derived from the Fokker–Planck collision term directly and is implemented to global Monte Carlo simulation code GNET[1], in which the linearized drift kinetic equation for energetic particles distribution, \( \delta f(x, v_{\|}, v_{\perp}, t) = f(x, v_{\|}, v_{\perp}, t) - f_{\text{max}}(r, v^2) \), is solved in 5-D phase space, introducing an iterative process.

In order to conserve the momentum, we assume the particle collision term of \( \delta f(x, v_{\|}, v_{\perp}, t) \) as \( C^{\text{coll}}(\delta f) = C(\delta f, f_{\text{max}}) + C(f_{\text{max}}, \delta f) \), where \( C(f_{\text{max}}, \delta f) \) is the field particle operator which represents the collision effect for the background particles. The field particle operator can be expressed using Legendre polynomials and, introducing the Trubnikov-Rosenbluth potential, we can derive the field particle term for each Legendre polynomials, \( C_n(f_{\text{max}}, \delta f^{(n)}(v)) \). Once the field particle operator is obtained we can consider \( C(f_{\text{max}}, \delta f) \) as a new source term in the drift kinetic equation.

In the GNET code, we introduce an iterative process to implement the momentum conserving collision operator. We first obtain the steady state solution, \( \delta f_0 \), assuming an original source term, \( S^{\text{old}} \) and evaluate \( C(f_{\text{max}}, \delta f_0) \), which becomes a new source term. Next we obtain a steady state solution, \( \delta f_1 \), with this new source term and evaluate \( C(f_{\text{max}}, \delta f_1) \). Then we iteratively obtain \( \delta f_n \) until the lost momentum close to zero.

The developed model is applied to the ECCD simulation of the heliotron-J[2]. The simulation results show a good conservation of the momentum and the increment of ECCD current is observed.