Two-Dimensional Full Particle Simulation of the Formation of Electrostatic Field in a Tokamak Plasma

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It is widely recognized that the electric field (or $E{\times}B$ drift flow shear) significantly affects the transport of the magnetically confined plasma, but it has not fully been understood how the electric field is formed. The stationary electropstatic field is determined so that electron and ion particle transports are balanced. In an open-field configuration, such as SOL/ divertor plasmas, electrons flow out faster to the wall, and the SOL plasma potential becomes positive against the wall. On the other hand, in an axisymmetric closed-field configuration such as a tokamak core plasma, the cross-field transport is mainly ambipolar, and it is not obvious which flows out faster. The effect of SOL region on the core region is not fully clarified as well. A two-dimensional full particle code, PARASOL [1,2], is applied to study this subject. The simulation system consists of an axisymmetric-toroidal conducting vessel with rectangular poloidal cross section. A tokamak plasma is confined in a double-null magnetic field configuration. The electrostatic potential, including the sheath potential in front of the wall, is self-consistently calculated with a particle-in-cell method. Orbits of ions are fully traced, while guiding-center orbits are followed for electrons. Coulomb collisions are given with a Monte-Carlo binary collision model. In addition, anomalous transport across the magnetic field lines is simulated with a Monte Carlo technique. Hot particles are supplied in the central region, and the plasma is diffused across the magnetic field to the SOL region.

The PARASOL simulation indicates that the normalized Larmor radius (NLR) is the key parameter for the potential profile in a tokamak plasma with infinitely large aspect ratio. When the NLR is small, the whole potential profile is monotonically upward convex. As the NLR increases, the profile becomes hollow in the core region. In a tokamak plasma with finite aspect ratio, the hollow profile is observed even for the smaller NLR condition. We investigate the effects of aspect ratio, NLR and collisionality on the formation of the electrostatic field. Characteristics of the spontaneous plasma flow is also studied

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