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Neoclassical Transport Calculation for ST Plasma

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Abstract

In assessing the confinement properties of toroidal plasmas, it is important to accurately calculate the neoclassical dynamics, which set the irreducible minimum level of transport in such systems. While much attention is paid to turbulent transport studies, there remain significant unresolved neoclassical issues – especially in spherical torus experiments such as NSTX. In the NSTX plasmas, typical features which violate basic assumptions of most theories include low aspect ratio, large orbit size, large trapped particle fraction (up to ∼100%), large toroidal rotation with strong shear, etc. When these effects are properly taken into account, together with self-consistent calculation of the equilibrium electric field, it is obviously of interest to assess the possible strong impact on ion thermal transport and the bootstrap current. In the present investigation, the neoclassical physics of ST plasmas is systematically studied using a generalized particle-in-cell (PIC) 3-dimensional code, which employs the delta-f method to solve the drift kinetic equations together with the Poisson equation governing the ambipolar electric field in general toroidal geometry. The main physical and numerical features of the code include:

- full global geometry effects
- dynamics of the self-consistent electric field in both the radial and poloidal directions
- finite orbit effects (nonlocal transport) which may have a significant influence on neoclassical transport near the magnetic axis and in the region of large plasma gradients
- systematic treatment of plasma rotations
- ions and electrons at present, multi-species (energetic particles and impurities) to be developed
- accurate Lagrangian equations recently developed for guiding-center motion calculations
- a coordinate system with approximately equal arc length, which allows a uniform grid in the poloidal direction and a better representation of numerical equilibria for high beta, strongly shaped plasmas

The present code has first been carefully benchmarked in the large aspect ratio circular geometry limit with neoclassical theory and with existing codes, such as FORTEC-E. General geometry simulations are then used to assess plasma transport due to collisional relaxation in an ST plasma, such as NSTX. This includes evaluation of the ion thermal flux, radial electric field dynamics and structure, poloidal flow, angular momentum transport, and bootstrap current.

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