Finite banana width effects on NTM threshold physics

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Magnetic islands have a deleterious effect on tokamak confinement, and unchecked neo-classic tearing modes (NTMs) threaten successful ITER operation. A successful NTM control system requires a more complete understanding of the physics of how islands heal themselves below a threshold width, \( w_c \). Both theory and experiment suggest that \( w_c \) is comparable to the trapped ion banana width, \( \rho_b \). We have developed a new drift kinetic theory by expanding in the ratio of island width, \( w \), to the plasma minor radius, \( r \), whilst retaining the order \( w \sim \rho_b \) and including orbit averaged equations for the particle responses. Also included in our model is a momentum-conserving collision operator.

We have tackled this model both from analytic and computational positions. Analytically, we neglect collisions at leading order, reintroducing them at higher order to provide a constraint to an otherwise free profile. Our analytic solutions show that the particle drift orbits have the same geometry as the magnetic island flux surfaces, but shifted in the radial direction. The magnitude of this shift is proportional to the poloidal larmor radius, a measure of orbit width, while the direction depends on the sign of the parallel velocity. The distribution functions is then flattened across these drift island structures, and not on the magnetic island structure itself.

Meanwhile, numerical simulations show that, close to the threshold, finite particle orbits lead to incomplete flattening of the density profile, especially in a layer surrounding the separatrix. In the parallel ion velocity, there exists a boundary layer, up to \( O(\rho_b/w) \) in width. These effects are significant even if the particle orbits are as narrow as \( 0.1w_c \).

Taken together, these results are significant for NTM threshold physics, as finite particle orbit width effects must be retained, even for small orbit widths.

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