Neoclassical tearing mode induced by error field penetration

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In tokamaks, magnetic islands are generated by both the neoclassical tearing mode and the forced magnetic reconnection due to intrinsic or externally applied error fields. In addition, interaction between the neoclassical tearing mode and error fields is of great importance in tokamaks. It is known that the rotating neoclassical tearing mode is decelerated and locked by error fields, once error field amplitude exceeds a critical value. Even when the neoclassical tearing mode is stable, penetration of error fields directly produces non-rotating magnetic islands that continue growing due to plasma responses, which are so-called born-locked modes. Those locked modes are often observed in precursor phases of tokamak disruptions[1].

Much work has been done to understand interaction between the *unstable* neoclassical tearing mode and the error fields. For example, in our previous work, a low dimensional model of rotating magnetic islands is introduced to understand simulation results based on reduced magnetohydrodynamic (MHD) equations[2]. While, a relation between the *stable* neoclassical tearing mode and the error fields has not been fully discussed so far.

In this study, a simulation code solving reduced MHD equations in two-dimensional slab geometry is developed to study the effects of error fields on the stable neoclassical tearing mode. The reduced MHD equations are composed of a vorticity equation, a generalized Ohm's law and a pressure evolution equation. Perturbed bootstrap currents are phenomenologically introduced in the generalized Ohm's law. The error fields are introduced through edge boundary conditions of magnetic flux perturbations. Nonlinear simulations are conducted in parameter regimes, where the neoclassical tearing mode is stable for any initial magnetic island width.

In simulations, the error field penetration is observed, when plasma flow velocity and diamagnetic drift velocity almost cancel out. Once the error field penetration occurs, magnetic islands grow to sizes much larger than those expected from given error field amplitude. This indicates that the error field penetration destabilizes the stable neoclassical tearing mode. Our results are suggestive to a mechanism of spontaneous growth of the born-locked modes.

References

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