Nonlinear simulations of locking for finite β and favorable average curvature

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We present NIMROD simulations of error field locking behavior in plasmas with finite β. The equilibria investigated have weakly damped linear tearing modes stabilized by pressure gradient and favorable average curvature. Linear theory shows that the Glasser effect, the stabilization of tearing modes with favorable average curvature and positive Δ', occurs in the viscoresistive as well as the resistive-inertial regime[1], and this stabilization occurs in the presence of real frequencies. The simulations were performed in a periodic cylinder with a hollow pressure profile to simulate the toroidal effect of favorable curvature for $q > 1$. Linear NIMROD simulations with rotation and an error field of magnitude ψ_w show, for very weakly damped tearing modes, that the maximum reconnected flux occurs at the tearing mode phase velocity and the (quasilinear) Maxwell torque is zero there, as predicted in Ref. 2. In nonlinear simulations, on the other hand, these effects of real frequency tearing modes and stabilization by favorable average curvature are very often masked by the flattening of the pressure profile near the mode rational surface due to sound wave propagation there, similar to the destabilization of large amplitude drift tearing modes, which can lead to faster growth[3]. This pressure flattening can destabilize the mode, and the interaction of the field due to both ψ_w and to the destabilized tearing mode can lead to oscillations in the Maxwell torque, which can lead to islands that either freely rotate or are trapped in phase. We have also observed cases in which there are damped oscillations in Ω_t, the angular frequency at the mode rational surface, as well as undamped limit cycle oscillations in Ω_t. We describe the interplay of three nonlinear effects: nonlinear saturation of the tearing mode by current flattening; pressure flattening; and locking by the Maxwell torque.

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3. B. D. Scott, A. B. Hassam, J. F. Drake, “Nonlinear evolution of drift-tearing modes”, Phys. Fluids **28**, 275 (1985).