Nonlinear Stability of Field-Reversed Configurations with Self-Generated Toroidal Field

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Abstract

The Field-Reversed Configuration (FRC) is a high-beta compact toroidal plasma confinement scheme in which the external poloidal field is reversed on geometric axis by azimuthal (toroidal) plasma current. Using a quasi-neutral, hybrid, particle-in-cell (PIC) approach [Y.A. Omelchenko and R.N. Sudan, Phys. Plasmas **2**, 2773 (1995)] we study long-term nonlinear stability of realistic axisymmetric FRC equilibria to a number of toroidal modes, including the most disruptive tilt mode. In particular, self-generated toroidal magnetic field is found to be an important factor in mitigating the instability and preventing the confinement disruption. This is shown to be a unique FRC property resulting from the Hall effect in the regions of vanishing poloidal magnetic field. The instability-driven toroidal field stabilizes kink formation by increasing the magnetic field energy without destabilizing curvature-driven plasma motion. We also demonstrate nonlinear saturation of the tilt instability due to finite Larmor radius (FLR) effects and plasma relaxation to a quasi-steady kinetic state. During this transition the FRC is shown to dissipate a substantial amount of initially trapped flux and plasma energy. These effects are demonstrated for kinetic and fluid-like, spherical and prolate FRCs.

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