MHD stability of low-*n* modes in small aspect ratio tokamaks

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Abstract

We apply the M3D code [1] to the study of the dominant global instabilities in typical discharges in small aspect ratio tokamaks such as the Current Drive Experiment Upgrade (CDX-U). Equilibria with $q_0 \approx 0.95$ (and thus a $q=1$ rational surface no more than one-third of a minor radius out from the magnetic axis) exhibit a spectrum of linearly MHD-unstable modes with toroidal mode numbers $n=1$ and up, with the higher-n modes having higher growth rates, as previously observed in results from the NIMROD code [2]. Eigenmodes for low n ($\leq$ 3) typically cluster mainly at the $q=1$ rational surface, while for larger n the high resistivity of the low-temperature plasma at higher-q surfaces further from the plasma core results in high poloidal mode number m resistive ballooning modes about those surfaces.

We next investigate the nonlinear behavior of the low-n modes. The traditional expectation for the nonlinear evolution of the $m=1$, $n=1$ mode is that it will result in one or a series of sawtooth crashes, reconnection events that flatten the temperature profile and restore the equilibrium and may also nonlinearly trigger the formation of the higher-m seed islands of neoclassical tearing modes. While we observe this phenomenon under some conditions, there are a number of cases in which we instead find that the $n=1$ mode itself comprises a full spectrum of coupled poloidal modes at many rational surfaces. These modes can grow to substantial sizes before a single sawtooth crash occurs, thus providing an alternate mechanism for the generation of the seed islands. The implications of this MHD result are explored.

We also consider two-fluid effects, which are particularly pronounced in low-density, small major radius discharges such as those in CDX-U, and may change both the foregoing linear and nonlinear pictures considerably by stabilizing the higher-n modes. The effects of equilibrium flow on the stability of these modes are also considered.

[1]W. Park, et al., *Phys. Plasmas* **6**, 1796 (1999).
[2]D. Schnack, personal communication (2003).