

# 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.

<sup>1</sup>W. Park, et al., *Phys. Plasmas* **6**, 1796 (1999).

<sup>2</sup>D. Schnack, personal communication (2003).