The Role of Kinetic Effects, Including Plasma Rotation and Energetic Particles, in Resistive Wall Mode Stability

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Continuous, disruption-free operation of high-beta tokamaks requires stabilization of the resistive wall mode (RWM). Theoretically, the RWM is thought to be stabilized by energy dissipation mechanisms that depend on plasma rotation and other parameters, with kinetic effects being emphasized [1]. Experiments in NSTX show that the RWM can be destabilized in high rotation plasmas while low rotation plasmas can be stable, which calls into question the concept of a simple critical plasma rotation threshold for stability. The present work tests theoretical stabilization mechanisms against experimental discharges with various plasma rotation profiles created by applying non-resonant $n = 3$ braking, and with various fast particle fractions. Kinetic modification of ideal stability is calculated with the `MISK` code, using experimental equilibrium reconstructions. Trapped ions provide the dominant kinetic resonances, while fast particles contribute an important stabilizing effect. Unlike simpler critical rotation theories, kinetic theory allows a more complex relationship between plasma rotation and RWM stability. Wave-particle resonances between the plasma rotation and the precession drift and bounce frequencies lead to stability, while plasma rotation profiles in-between these resonances have weakened kinetic stability and are therefore susceptible to RWM instability [2]. High plasma rotation alone is insufficient to guarantee stability. Kinetic theory may explain how fast particle loss can trigger RWMs through the loss of an important stabilization mechanism. Kinetic stability analysis with the `MISK` code is also applied to an ITER advanced scenario equilibrium to determine the impact of plasma rotation and alpha particles on RWM stability.

Supported by the U.S. Department of Energy under contracts DE-FG02-99ER54524, DE-AC02-09CH11466, and DE-FG02-93ER54215.

References

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