Resistive Wall Mode Stabilization in Slowly Rotating High Beta Plasmas

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Recent DIII-D experiments have shown that the resistive wall mode (RWM) can be stabilized by plasma rotation at velocities of only a fraction of a percent of the Aflvén velocity. The stabilization of the RWM is an integral part of the high pressure, fully non-inductive advanced tokamak path towards a fusion reactor, and a prerequisite for any operational scenario in which the plasma pressure exceeds the ideal MHD no-wall kink stability limit. The low rotation threshold is obtained by reducing the applied torque with balanced neutral beam injection heating, while minimizing magnetic field asymmetries with non-axisymmetric correction coils. Stable discharges have been observed with plasma pressures up to 1.4 times the no-wall kink stability limit and toroidal ion rotation velocities (measured with charge exchange recombination spectroscopy using C VI emission) of less than 10 krad/s corresponding to 0.3% of the Alfvén velocity at the lowest order resonant surfaces, which is a factor of 2 to 5 smaller than thresholds previously obtained by applying a torque with non-axisymmetric magnetic fields. The wide range of rotation profile shapes obtained on DIII-D allows for a stringent test of theories for RWM stabilization by plasma rotation. Initial calculations indicate that the kinetic damping model [1] can explain the low rotation threshold. The importance of further kinetic contributions [2] and two fluid effects will be discussed. The RWM stability is also investigated using active MHD spectroscopy, which in principle can yield real-time measurements of the growth rate and rotation frequency of the mode, while the plasma is still stable. Comparing the direction of the measured mode rotation with the plasma rotation indicates a significant stabilizing contribution from a region near the plasma edge (ρ>0.8). Despite the low rotation threshold, RWM feedback control using non-axisymmetric coils has been essential to routinely operate DIII-D above the no-wall limit. While slow feedback provides the dynamic error field correction required to sustain the plasma rotation on slow time scales, fast feedback is often necessary to mitigate the effect of transient perturbations such as edge localized modes, which otherwise could lead to strong braking of the rotation and trigger a pressure collapse.

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