Resistive Stability of 2/1 Modes Near 1/1 Resonance*

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The stability of multiple coupled resistive modes is examined using reconstructions of experimental equilibria in the DIII-D tokamak, revealing the important physics in mode onset as discharges evolve to instability. Experimental attempts to access the highest beta in tokamak discharges, including hybrid discharges, are typically terminated by the growth of a large 2/1 tearing mode. In hybrid discharges the plasma current is significantly non-inductive, intended to lengthen the discharge time, while sustaining the baseline dimensionless parameters of a burning plasma experiment. Model equilibria, based on experimental reconstructions from these discharges, are generated varying qmin and pressure. For each equilibrium the PEST3 code is used to determine the ideal MHD solution including both tearing and interchange parities at all resonant surfaces. This outer region solution must be matched to the resistive inner layer solutions at each rational surface to determine resistive mode stability. From this analysis we find that the approach to q=1 resonance simultaneously causes the 2/1 mode to become unstable and the nonresonant 1/1 displacement to become large, as the ideal beta limit rapidly decreases toward the experimental value. Here the 2/1 mode grows to a large size, leading to loss of confinement. However, this nonresonant 1/1 component is strongly coupled to the 2/2 harmonic of the unstable 3/2 mode, which is thought to contribute to the current drive sustaining q_{min} above 1 in hybrid discharges. Thus, the approach to q=1 resonance is self-limiting. Nonlinear coupling to the n=2 mode is computationally investigated using the NIMROD code. This work suggests that sustaining q_{min} slightly above 1 will help avoid the 2/1 and allow access to significantly higher beta values in these discharges.

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