Free-boundary Magnetohydrodynamic Simulations of DIII-D Tokamak Plasmas with NIMROD

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Linear ideal magnetohydrodynamic codes have long been used to predict the operating limits of tokamak experiments. As accurate equilibrium reconstructions have become available, the ability to compare the spatial structure of the linear eigenfunctions with diagnostic measurements for ideal modes [1] and to compare with analytic predictions of the time behavior of the mode onset [2] has become possible for a certain number of discharges. A successful example of this comparison is the analysis of the disruption event which occurred in DIII-D shot #87009 where a faster-than-exponential mode growth was observed as the plasma was heated past the marginal stability point.[2] Although successful in prediciting the onset and mode structure, many features of the disruption event remain unknown, especially the deposition mechanisms of the internal energy. In the present work, initial-value, nonlinear simulations of DIII-D shot #87009 are performed with the NIMROD code. The simulations include the region beyond the separatrix to provide an opportunity to do unprecedented theoretical-experimental comparisons. Starting with an equilibrium that is submarginal to the ideal mode, a heating source is applied to heat it above the marginal threshold. As predicted by the analytic theory, the mode grows faster than exponential on a time scale that is hybrid between the heating time scale and an ideal MHD time scale. Unlike conventional wisdom which held that the energy loss occurs as the plasma kinks and strikes the wall, these simulation suggest that energy loss occurs as the plasma becomes nonlinear, and forced reconnection causes the magnetic field to become stochastic. Because the field is especially susceptible to stochasicization near the X-points, rapid heat loss from anistotropic thermal conduction deposits energy primarily to the divertor region. The heat fluxes from thermal conduction alone are too high for material walls and divertors. A simple model for radiative losses due to impurities is introduced to provide a separate loss mechanism. Accurate modeling of disruption events will require an active collaboration between the MHD and edge subfields.

[1] A.D. Turnbull et.al. In the Proceeding of the 18th Fusion Energy Conference, IAEA, Sorrento, Italy (2000)

[2] J.D. Callen et.al., Phys. Plas. **6,** 2963 (1999)