APR06-2006-000670

Abstract for an Invited Paper
for the APR06 Meeting of
the American Physical Society

Magnetic Reconnection in the DIII-D Tokamak[1]

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Magnetic reconnection is an important feature of tokamak plasmas, with the resulting changes in magnetic topology often leading to redistribution of the plasma's thermal and magnetic energy. Improved experimental diagnostics, including direct measurements of the internal magnetic field, and large nonlinear 3D numerical simulations have begun to offer new views of tokamak magnetohydrodynamic (MHD) instabilities. The full potential of these tools for investigation of reconnection physics and quantitative comparison of theory and experiment has yet to be exploited. This talk summarizes several areas of research related to reconnection in the DIII-D tokamak. The sawtooth is a periodic reconnection with poloidal and toroidal mode numbers m=1, n=1 that occurs in the core of a tokamak plasma. DIII-D results demonstrate a wide range of sawtooth behavior in different plasma regimes, ranging from fast, complete reconnection of the core region (similar to the classic Kadomtsev model) to a quasi-interchange-like instability with slower reconnection. Reconnection often leads to tearing modes and magnetic islands at flux surfaces with rational safety factors $q=m/n>1$. At low plasma pressure, the onset and growth of tearing modes in DIII-D are in good agreement with the classic stability index Δ'. At higher pressure the evolution and saturation of "neoclassical tearing modes" agrees well with the Rutherford equation, modified to include the pressure-driven bootstrap current. Forced reconnection is also important in tokamak plasmas. Tearing modes may be driven by external magnetic field errors or by other MHD events. However, plasma rotation at the resonant surface can shield the driving perturbation and inhibit reconnection, leading to nonlinear threshold behavior as observed in DIII-D and other experiments. The shielding becomes stronger as the Lundquist number increases, a possibly favorable result for larger, hotter, stronger-field fusion devices of the future.

[1]Work supported by US DOE under DE-FC02-04ER54698