Neoclassical Tearing Modes and Their Control *

R.J. La Haye, General Atomics

A principal pressure limit in tokamaks is set by the onset of neoclassical tearing modes (NTMs), which are destabilized and maintained by helical perturbations to the pressure-gradient driven "bootstrap" current. The resulting magnetic islands break up the magnetic surfaces that confine the plasma. The NTM is linearly stable but nonlinearly unstable, and generally requires a "seed" to destabilize a metastable state. In the past decade, NTM physics has been studied and its effects identified as performance-degrading in many tokamaks, including ASDEX Upgrade, COMPASS-D, DIII-D, JET, JT-60U, MAST, NSTX, T-10, TCV, TEXTOR, and TFTR. The validation of NTM physics, suppressing the NTMs, and/or avoiding them altogether are areas of active study and considerable progress. Recent joint experiments on ASDEX Upgrade, DIII-D, and JET, for example, give new insight into the underlying physics, seeding, and threshold scaling of NTMs. The physics scales towards increased NTM susceptibility in ITER, underlining the importance of both further study and development of control strategies. These strategies include regulation of "sawteeth" to reduce seeding, using static "bumpy" magnetic fields to interfere with the perturbed bootstrap current, and/or applying precisely located microwave power current drive at an island to stabilize (or avoid destabilization of) the NTM. Sustained stable operation without the highly deleterious m=2, n=1 island has been achieved, for example, at a pressure consistent with the no-wall n=1 ideal kink limit, by using electron cyclotron current drive at the q=2 rational surface, which is found by real-time accurate equilibrium reconstruction. This improved understanding of NTM physics and stabilization strategies will allow design of NTM control methods for future burning-plasma experiments like ITER.

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