

Control of Neoclassical Tearing Modes

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Experiments on several tokamaks have shown that the plasma beta may be limited by the occurrence of modes well below the ideal MHD beta-limit. Mostly, these modes lead to a saturation or rollover of the beta, and they are identified as neoclassical tearing modes (NTM). Extrapolation of current experimental results shows that these modes could form a serious limitation to the achievable plasma beta in tokamak reactors the size of ITER. Neoclassical tearing modes are truly nonlinear instabilities: The linear tearing mode generally is stable as indicated by a negative Delta-prime. However, the generalized Rutherford equation describing the evolution of a finite size magnetic island includes a destabilizing contribution, which results from a perturbation of the neoclassical bootstrap current due to the flattening of the pressure profile across the magnetic island. When the beta exceeds a certain critical value, the generalized Rutherford equation predicts the growth of a magnetic island once it is seeded at some critical finite width. The growth of the mode thus requires seeding by some other magnetic perturbation. For example, a $3/2$ NTM is generally seeded through toroidal coupling by the $2/2$ component of a sawtooth precursor. This process of seeding has received little attention in the literature. Most work on the control of neoclassical tearing modes has been focused on the stabilization of the mode once it has been formed. For example, current drive inside the magnetic island can substitute the missing bootstrap current and reverse the growth of the magnetic island. This has been proven successful with ECCD in ASDEX-Upgrade, and is proposed as the main way of NTM control for ITER. An other term in the generalized Rutherford equation, that one can act on to improve stability, is Delta-prime through changes in the local current density profile. This has been employed successfully on COMPASS-D with LHCD. Alternatively, however, one could act on the seeding perturbation. This has been the purpose of recent experiments carried out under EFDA by Taskforce M on JET. Here ICCD has been performed near the $q=1$ surface, in order to destabilize sawteeth and obtain smaller sawtooth period and amplitude. The experimental results confirm that higher beta values can be reached before the $3/2$ NTM is triggered, when smaller period sawteeth are created by ICCD just outside the sawtooth inversion radius. On the other hand, monster sawtooth collapses, generated by energetic ion sawtooth stabilization with central ICRH, are found to trigger NTMs at relatively low beta that would have been stable in case of heating by Neutral Beam Injection only.