Simulations of Saturated Tearing Modes in Tokamaks

C.N. Nguyen, G. Bateman, A.H. Kritz

Lehigh University Physics Department
16 Memorial Drive East, Bethlehem, PA, 18015, USA

Abstract

A quasi-linear model, which includes the effect of the neoclassical bootstrap current, is developed for saturated tearing modes in order to compute magnetic island widths in axisymmetric toroidal plasmas with arbitrary aspect ratio, cross-sectional shape, and plasma beta [1]. The theory is derived using three-dimensional scalar plasma pressure force balance, leading to a set of ordinary coupled differential equations. The presence of a magnetic island at each mode rational surface has the effect of locally flattening the pressure and current density profiles, which then results in removing the singularity from the set of coupled differential equations for each helical harmonic of the perturbed magnetic field. Consequently, the set of coupled ordinary differential equations for all the helical harmonics can be integrated from the magnetic axis to the outer boundary conditions. In the resulting algorithm, the widths of the magnetic islands within the plasma are effectively non-linear eigenvalues for the two-point boundary value problem. This quasi-linear technique for determining saturated magnetic island widths has the advantage that any number of geometrically coupled harmonics with different mode rational surfaces can be integrated from the magnetic axis out to whatever boundary conditions are appropriate at the wall. That is, the magnetic island widths are adjusted so that the solution of ordinary differential equations for all the helical harmonics of the helical perturbation satisfies the boundary conditions at the magnetic axis and at the wall. The model is implemented in the BALDUR integrated predictive modeling code. The local enhancements in the transport produced by magnetic islands have a noticeable effect on global plasma confinement in simulations of low aspect ratio, high beta tokamaks, where saturated tearing mode islands can occur with widths that are greater than 15% of the plasma minor radius.

[1] G. Bateman and R.N. Morris, *Physics of Fluids* **29**,753 (1986).

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