Nonlinear growth of tearing modes:
validating the generalized Rutherford equation

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The nonlinear growth of neoclassical tearing modes (NTMs) in tokamaks is commonly discussed in the framework of the generalized Rutherford equation (GRE) [1, 2]. Results from the GRE qualitatively match experimental observations of NTM growth and their stabilization by electron cyclotron current drive (ECCD) [3]. To anticipate requirements for the suppression of NTMs by ECCD in future machines such as ITER, the GRE is being used extensively. A thorough numerical validation of the GRE on 2 and 3 dimensional MHD modelling is needed.

We present results from a 2D reduced MHD code that is developed specifically to validate the generalized Rutherford equation. To match the assumptions used to derive the Rutherford equation, the island width is assumed to be small, and cylindrical and toroidal effects are neglected. Under these assumptions, the region encompassing a magnetic island is modeled as a planar slab with periodic boundary conditions in the direction of the helical angle. Radial boundary conditions are provided by the linear, ideal MHD equations in the exterior region. The code uses finite differences in the radial direction and a Fourier expansion in the helical angle. In the early linear phase of the mode, the exponential growth matches the predicted growth rate. When the island width exceeds the resistive layer width, the mode enters into the nonlinear regime and the island width grows proportional to time in quantitative agreement with the Rutherford equation. Only the fundamental Fourier harmonic is found to play a significant role, with higher harmonics remaining very small. The next step toward validation of the GRE in two dimensions will be the implementation of a flux-surface-averaged EC-driven current density. In particular, we will focus on possible effects of the higher Fourier harmonics of the EC-driven current that are not taken into account in the Rutherford equation, but which can be significant due to the very localized nature of the ECCD [4]. Eventual broader applications of the code will be discussed.

References