Nonlinearly perturbed MHD equilibria, with or without magnetic islands

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An understanding of tokamaks, including error-fields and ELM control, requires an understanding of the effects of non-axisymmetric magnetic fields. An important issue is to what extent will surface currents arise that shield magnetic perturbations, or to what extent will the plasma will relax and reconnect, resulting in the formation of magnetic islands and stochastic regions.

We base our model of non-axisymmetric equilibria on a constrained energy principle that accomodates both scenarios by combining ideal MHD with Taylor relaxation theory, and allows equilibria with or without chaotic fields to be constructed with arbitrary pressure and safety-factor profiles; and, for which the existence of solutions for slightly perturbed configurations is guaranteed [Bruno & Laurence, 1996]. The plasma is comprised of nested annular regions which are separated by toriodal interfaces that act as ideal barriers and may support pressure. Equilibrium states minimize the plasma energy, subject to the constraints of conserved helicity and mass in each annulus. Arbitrarily many ideal interfaces may be included, so that globally ideal-MHD equilibrium states can be constructed. Alternatively, local relaxation at the rational surfaces is allowed. This model is implemented numerically in the recently-developed, Stepped Pressure Equilibrium Code, SPEC.

SPEC allows the topological constraint of ideal MHD to be enforced at the rational surfaces, thus preventing island formation. In this case, SPEC is similar to a non-linear generalization of the IPEC code. On relaxing the ideal constraints locally in the vicinity of the rational surfaces, SPEC allows the resonant perturbations to create magnetic islands. Global relaxation is prevented by enforcing the ideal constraints at surfaces with strongly irrational rotational-transform. Results illustrating the effects of resonant magnetic perturbations in both cases will be presented.