Integration of Global Stability into the Simulation of a Burning Plasma Experiment

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Burning-plasma magnetic fusion experiments necessarily operate with parameters that lead to a wide separation of time scales. In the foreseeable future, the only possibility for an "integrated simulation" of a burning plasma experiment is to use a number of different codes that are capable of exchanging information with one another, and that solve successively different sets of reduced plasma equations. The "transport timescale" code solves a set of equations obtained by averaging over all Alfven-wave and faster activity. It evolves a sequence of 2D equilibrium though time by alternatively integrating the surface averaged transport equations and solving an elliptic equation that enforces 2D force balance. These equilibrium need to be monitored against linear stability criteria, and as one is approached, the same equilibrium needs to be passed to a non-linear MHD code to calculate the nonlinear evolution of that instability, and it's effect on modifying that equilibrium.

The need for a nonlinear global 3D MHD calculation arises from many separate but related phenomena. These are: sawtooth oscillations, neoclassical tearing modes (NTMs), disruptions caused by short wavelength modes interacting with long wavelength modes, pellet injection, TAE modes, edge localized modes (ELMs) and the need to calculate vessel forces and heat loads during a major disruption and vertical displacement event. There may also be a need to calculate the evolution of resistive wall modes (RWM) in advanced operating scenarios. These modes are well described by extended MHD equations utilizing either a two-fluid or a hybrid particle/fluid closure. Nonlinear 3D MHD codes addressing these issues need to deal with the computational problems of multiple timescales, multiple space scales, extreme anisotropy, and the modeling of essential kinetic effects.

The Center for Extended MHD Modeling (CEMM) is a SciDAC project that has joined together the efforts and capabilities of the M3D and NIMROD codes and code-development teams, and has developed a new adaptive mesh refinement MHD code (AMRMHD). We have made much progress in addressing many of these numerical difficulties by using implicit methods, adaptive meshing, unstructured meshes, high-order finite elements, and hybrid particle/fluid models. One current focus is to perform realistic modeling of a small tokamak, CDX-U, to demonstrate benchmarking of an integrated model against real experimental data.

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