Nonlinear MHD and Energetic Particle Modes in Stellarators

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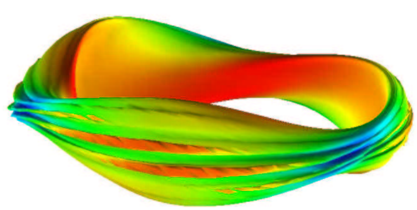
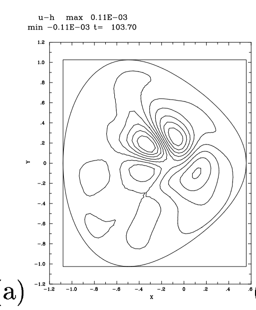
The M3D (Multi-level 3D) project [1] carries out simulation studies of plasmas using multiple levels of physics, geometry, and grid models. M3D combines a two dimensional unstructured mesh with finite element discretization in poloidal planes and fourth order finite differencing in the toroidal direction. The code is parallelized and runs on both shared and distributed memory computers.

The M3D code has been applied to ideal, resistive, two fluid, and hybrid simulations of compact quasi axisymmetric stellarators. Equilibria are initialized with the VMEC code [2]. M3D equilibria agree well with VMEC, except that M3D magnetic fields can contain islands. In ideal MHD simulations, when β exceeds a threshold, low poloidal mode number ($m \sim 6-12$) modes grow exponentially, clearly distinguishable from the equilibrium evolution. The β limit found for NCSX is significantly higher than the infinite mode number ballooning limits. In the presence of resistivity, these modes occur well below the ideal limit. Their growth rate scaling with resistivity is similar to tearing modes. With sufficient viscosity, the growth rate becomes slow enough to allow calculations of magnetic island evolution. Islands found by M3D are consistent with PIES [3] results.

Hybrid gyrokinetic simulations with energetic particles indicate that global shear Alfvén TAE - like modes can be destabilized in stellarators, as in tokamaks. Computations in a two - period compact stellarator obtained a predominantly $n = 1$ toroidal mode with about the expected TAE frequency $V_A/(2qR)$ at the q=2.5 surface. Work is in progress to study fast ion-driven Alfvén modes in NCSX.



(a)



(b)

(a) Pressure isosurface in a ballooning unstable NCSX stellarator design (b) electrostatic potential in a TAE - like mode in a period two stellarator

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Supported by U.S. DOE grant DE-FG02-86ER53223 and contract DE-AC02-76-CHO-3073