Center for Extended Magnetohydrodynamic Modeling (CEMM)

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The overarching theme of our center is to go beyond the resistive magnetohydrodynamic model of a fusion plasma towards a more complete description, and to implement these improved models on the most worlds most powerful computers to obtain a unique predictive capability allowing us to better understand the macroscopic dynamics of fusion plasmas. We have made significant progress on several fronts during the last year. These were presented at two project meetings, which have been documented on the site: http://w3.pppl.gov/CEMM, and at several conferences, and in at least 14 journal articles during this period.

Introduction: We describe ongoing code development and application activities during the last year within the CEMM.

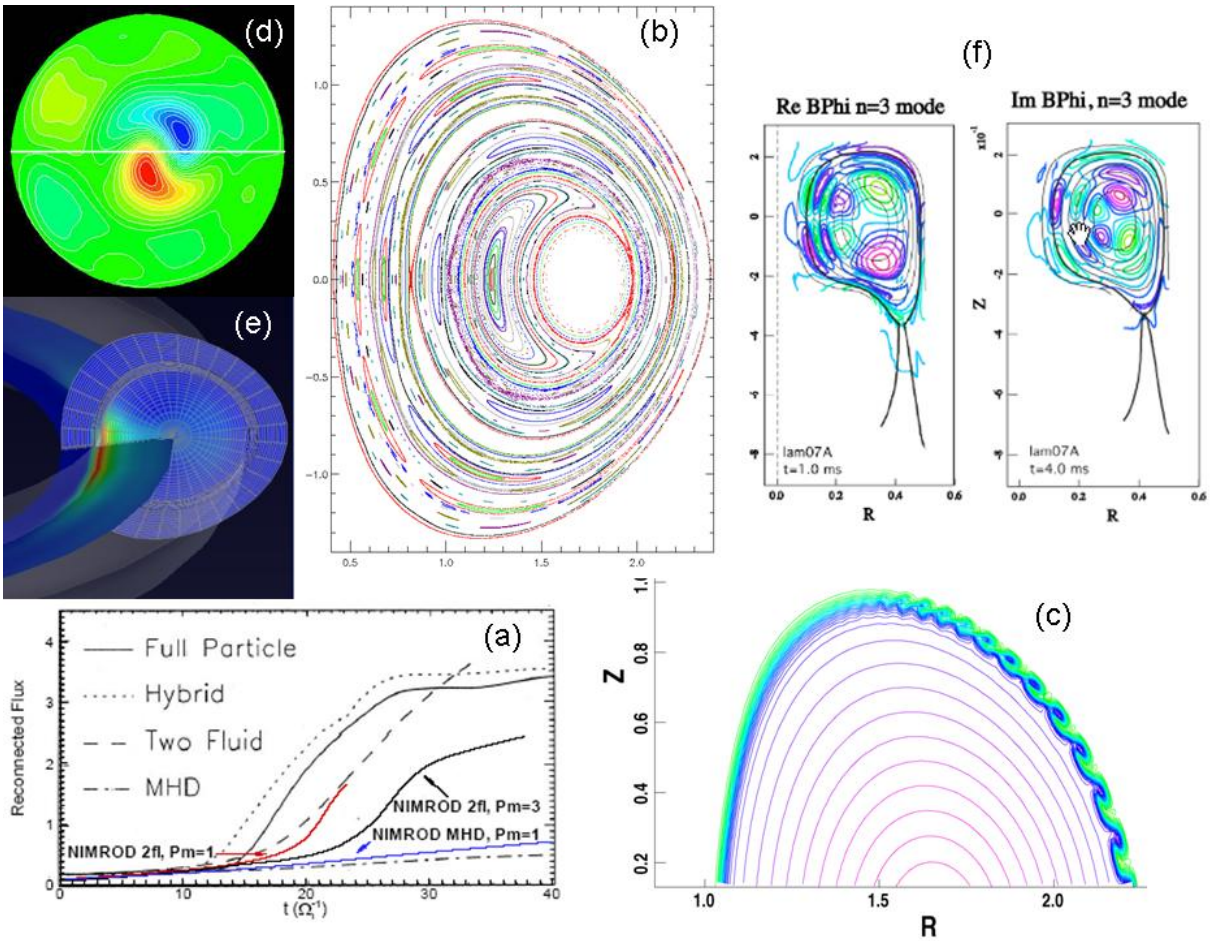
Spatial Discretizations: We have been investigating the efficacy of higher order triangular finite elements for the existing M3D code, as well as for the developmental M3D-C^1 code. A new class of 2nd or 3rd order spectral elements look especially promising for M3D as they yield not only improved accuracy, but a diagonal mass matrix which fits well with the existing structure and does not substantially increase running time. The reduced quintic C^1 elements have now been applied to an implicit full 6-field 2-fluid MHD model. They give excellent results if the structure of the solution is adequately resolved, but the relative efficiency compared to other methods needs to be further evaluated. Adaptive techniques are being explored.

Two fluid MHD and associated Temporal Differerncing: A general expression for the gyroviscous force has been obtained that is free of previous assumptions and suitable for implementing in 3D initial value codes. The NIMROD and M3D-C^1 codes now have implicit 2-fluid algorithms implemented for the gyroviscous, whistler, and kinetic alfven terms. Verification runs have been performed on the GEM test problem. (1a).

Numerical Closures: Integral CEL closures have been implemented in NIMROD for the thermal conductivity, and are now being tested for the parallel ion stress.

Sawtooth Modeling: Subtantial progress has been made on the CDX-U sawtooth (1b) simulations with both M3D and NIMROD. The nonlinear MHD simulations with actual device parameters are capable of tracking the evolution through repeated sawtooth events, with a computed period within 25% of the experimental period. The surfaces pass through a semi-stochastic region that does not destroy confinement. Future emphasis is to improve the boundary conditions, source terms, and two-fluid model to obtain improved agreement.

Elm Modeling: Initial results on the modeling of ELMs in DIII and ITER have



been obtained. The NIMROD DIII results show much similarity with the linear ideal MHD results, but illustrate the importance of non-ideal effects. Modeling far into the nonlinear regime presents severe numerical challenges (1c).

Hybrid Calculations: The NIMROD and M3D codes now both have a hybrid particle/fluid option and give agreement on the energetic particle test problem. A new study has been performed of the nonlinear dynamics of the fishbone instability (1d) showing the importance of both the particle and fluid nonlinearties. This shows both frequency chirping and a significant distortion of the particle distribution function.

Adaptive Mesh Refinement: The AMR code has now been converted to magnetic coordinates (1e), an implicit version is being developed, and applications are being extended to supersonic jet injection.

Spheromak Modeling: NIMROD modeling of the SSPX spheromak (1f) continues to be a useful tool to guide and understand the experimental results. Both experiment and modeling shows a similar dependence on the gun current to flux ratio λ and the importance of low-order rational surfaces in determining the mode structure and peak temperature.

Visualization: A common NIMROD/M3D AVS viewer is in place to facilitate code comparisons. Advanced techniques are being explored in the areas of vortex cores, stream surfaces, and critical points.

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