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 fluid/hybrid description, and to implement these improved models on leading-edge computers to obtain unique predictive capabilities allowing us to better understand and to predict the macroscopic dynamics of fusion plasmas. We have made significant progress on several fronts during the last year. These were presented at four project meetings, which have been documented on the site: http://w3.pppl.gov/CEMM, and in at least 24 journal articles and 7 invited talks during this period.

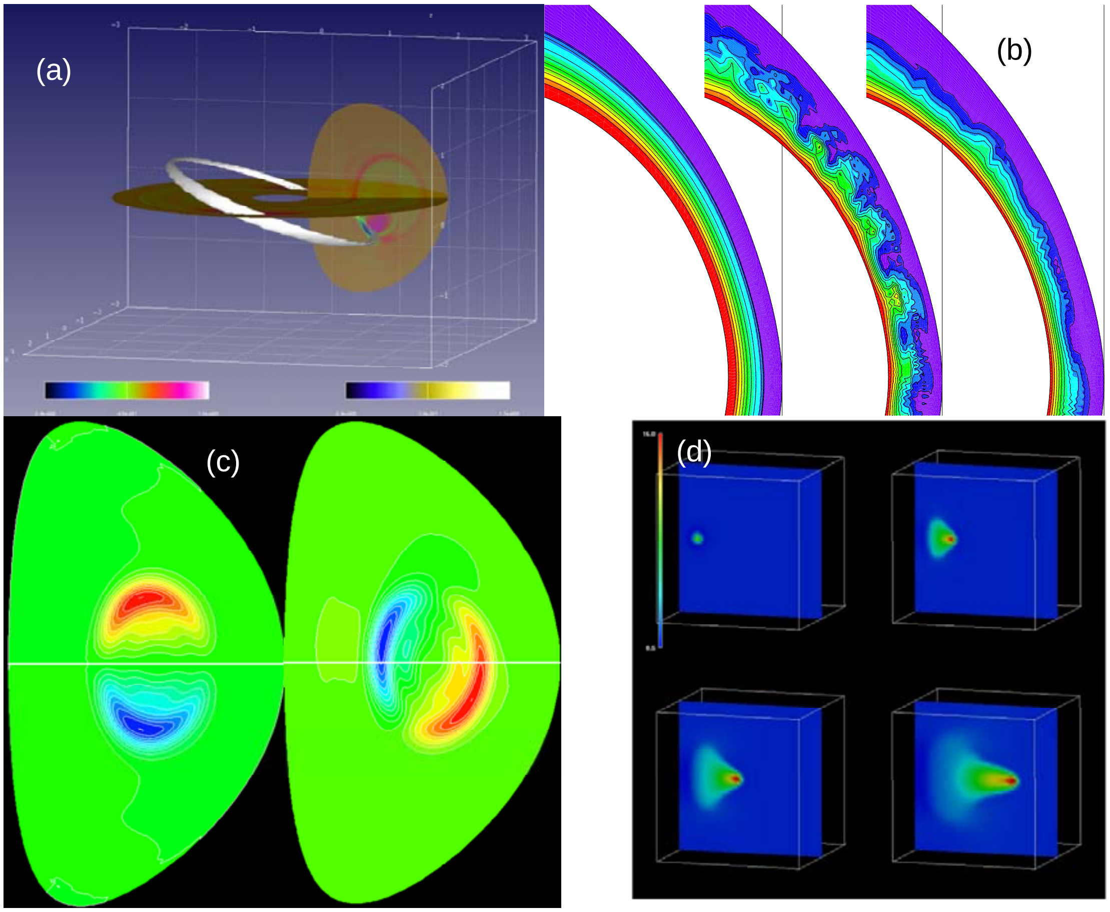
Introduction: We describe ongoing code development and application activities during the last year within the CEMM.

Improved models and associated numerical representations: [2,4,9,19,21] 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 Alfvén terms. Improved high-order elements have been implemented in the M3D code.

Code Benchmarks: [6,14,15,16,23] We have initiated several important benchmark activities Detailed verification runs have been performed on the GEM test problem (nonlinear), the gravitational instability, and the internal kink/fishbone instability.

Sawtooth Modeling: Substantial progress has been made on the CDX-U sawtooth (a) 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. Convergence studies show the need for surprisingly high resolution in order to obtain convergent results. Future emphasis is to improve the boundary conditions, source terms, and two-fluid model to obtain improved agreement.

Elm Modeling:[13] 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 has now been carried out far into the nonlinear regime with M3D and shows the experimentally observed re-symmetrization (b). Present emphasis is on quantifying the various non-ideal effects and on improved understanding of the conditions that lead to the different experimental ELM types.



Hybrid Calculations of the Internal Kink/Fishbone in ITER: [7,8] The NIMROD and M3D codes now both have a hybrid particle/fluid option and give good agreement on the energetic particle test problem. A new study has been performed of the nonlinear dynamics of the internal kink and fishbone instability in elongated plasmas (c) showing that plasma shaping reduces alpha particle stabilization significantly. Also, retaining thermal ion kinetic effects in the hybrid description has been shown to be a significant effect, reducing the MHD growth rate by half.

Pellet Injection using Adaptive Mesh Refinement: [17,18,29] The AMR code has now been converted to magnetic coordinates for increased efficiency when applied to tokamak pellet fueling calculations (d). We have implemented a detailed local physics model including ablation, ionization and electron heating in the neighborhood of the pellet. The AMR technique mitigates the complexity of the multiple spatial scales in the problem, and now an implicit version based on the Newton-Krylov approach is being developed to deal with the wide range of temporal scales. In addition, applications are being extended to supersonic jet injection.

Other: In addition to the described activities, we have continued our applications to support ongoing spheromak [5,10,24] and tokamak [1,11,12,22] experiments.

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