THREE-DIMENSIONAL MAGNETOHYDRODYNAMIC (MHD) MODELING FOR Z-PINCH APPLICATIONS

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Researchers at Sandia National Laboratories must develop detailed models and understanding of the physics associated with different kinds of loads on the Z machine. These loads range from imploding wire arrays to anode-cathode geometries intended to drive isentropic compression waves. The overall 3D topology of the Z-pinch load will greatly affect the material dynamics. The response of the load must be modeled self-consistently with the rest of the Z machine.

Many details of the Z-pinch load response can be modeled by the magnetohydrodynamic (MHD) equations. Z-pinch MHD physics is dominated by moving material regions whose conductivity properties vary drastically as material passes through melt and plasma regimes. At the same time void regions are modeled as regions of very low conductivity. An implicit approach for magnetic diffusion is required. An arbitrary Lagrangian-Eulerian (ALE) hydrodynamics methodology on unstructured grids is combined with an approach using vector edge and face elements for the transient magnetics. Vector elements have degrees of freedom as circulations on edges and fluxes on faces and are a natural basis for modeling Maxwell equation systems. A robust discretization for 3D magnetic diffusion is obtained which is free from parasitic transients. However, a matching algebraic multigrid which deals properly with the null space of the curl curl stiffness matrix is essential from a practical point of view. To maintain the discrete divergence free property over the remap step, a constrained transport (CT) algorithm is applied. There is a natural association between edge and face elements and the CT algorithm. The Poynting energy crossing the anode-cathode gap is represented in the finite element formalism and an appropriate coupling can be made to a lumped element circuit equation system representing the Z-machine response. This presentation will provide an overview of the various critical technologies currently in place, discuss the CT algorithm and circuit equation coupling in more detail and comment on areas for future research.

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