Three-dimensional Z-pinch wire array modeling

Allen C. Robinson[a]
Christopher J. Garasi[a]

[a] *Sandia National Laboratories*
Albuquerque, NM 87185-0819
acrobin@sandia.gov
cjgaras@sandia.gov

The dynamics of Z-pinch wire array explosion and collapse are of critical interest to researchers at Sandia National Laboratories. The physics of this process can be approximated by the resistive 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. This challenging physical situation requires a sophisticated modeling approach matched by suf£cient computational resources to make progress in physical understanding.

We give an overview of the numerical techniques currently in place for modeling explosion and collapse of Z-pinch wire arrays. In particular, an Arbitrary-Lagrangian-Eulerian (ALE) operator split methodology for modeling the MHD equations on unstructured grids is described. An important component here is an implicit treatment of the magnetic diffusion equation represented using vector edge and face elements, which gives solutions that are free from parasitic transients. A matching algebraic multigrid must also be applied to deal with the large null space of the stiffness matrix. The Poynting energy crossing the anode-cathode gap is represented in the £nite element formalism, and an appropriate coupling can be made to a lumped element circuit equation system representing the Z-machine response. A constrained transport algorithm is applied to update the divergence free magnetic ¤ux density representation.

Subsequently, we give details of recent calculations simulating wire array explosion and collapse. These dif£cult calculations are accomplished in a wedge geometry on a multiprocessor Linux cluster. We show how the details of the initial perturbation seeding are captured by the equations to give a plasma morphology comparable to three-dimensional plasma streamers seen in experimental images.

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