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Electro-Thermal-Mechanical Simulation Capability Final Report

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Final Report
LDRD 04-ERD-086

Electro-Thermal-Mechanical Simulation Capability

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Executive Summary

This is the Final Report for LDRD 04-ERD-086, "Electro-Thermal-Mechanical Simulation Capability". The accomplishments are well documented in five peer-reviewed publications and six conference presentations and hence will not be detailed here. The purpose of this LDRD was to research and develop numerical algorithms for three-dimensional (3D) Electro-Thermal-Mechanical simulations. LLNL has long been a world leader in the area of computational mechanics, and recently several mechanics codes have become "multiphysics" codes with the addition of fluid dynamics, heat transfer, and chemistry. However, these multiphysics codes do not incorporate the electromagnetics that is required for a coupled Electro-Thermal-Mechanical (ETM) simulation. There are numerous applications for an ETM simulation capability, such as explosively-driven magnetic flux compressors, electromagnetic launchers, inductive heating and mixing of metals, and MEMS. A robust ETM simulation capability will enable LLNL physicists and engineers to better support current DOE programs, and will prepare LLNL for some very exciting long-term DoD opportunities.

We define a coupled Electro-Thermal-Mechanical (ETM) simulation as a simulation that solves, in a self-consistent manner, the equations of electromagnetics (primarily statics and diffusion), heat transfer (primarily conduction), and non-linear mechanics (elastic-plastic deformation, and contact with friction). There is no existing parallel 3D code for simulating ETM systems at LLNL or elsewhere. While there are numerous magnetohydrodynamic codes, these codes are designed for astrophysics, magnetic fusion energy, laser-plasma interaction, etc. and do not attempt to accurately model electromagnetically driven solid mechanics. This project responds to the Engineering R&D Focus Areas of Simulation and Energy Manipulation, and addresses the specific problem of Electro-Thermal-Mechanical simulation for design and analysis of energy manipulation systems such as magnetic flux compression generators and railguns. This project compliments ongoing DNT projects that have an experimental emphasis.

Our research efforts have been encapsulated in the Diablo and ALE3D simulation codes. This new ETM capability already has both internal and external users, and has spawned additional research in plasma railgun technology. By developing this capability Engineering has become a world-leader in ETM design, analysis, and simulation. This research has positioned LLNL to be able to compete for new business opportunities with the DoD in the area of railgun design. We currently have a three-year $1.5M project with the Office of Naval Research to apply our ETM simulation capability to railgun bore life issues and we expect to be a key player in the railgun community.

Publications

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