Modeling and Simulation of the MC3028 Firing Set

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Abstract

Stewardship of the enduring stockpile of nuclear weapons includes certifying extended-lifetime performance of energetic components. These components include electro-mechanical devices that store electrical energy in ferroelectrics and produce currents when their permittivity is reduced explosively. One such device is the MC3028 firing set, which is used in the W76 and W78 weapon systems. The MC3028 uses the slim-loop ferroelectric material PBZT since the low remanent polarization of PBZT renders it safe when a charging voltage is removed. The Enhanced Surveillance Program supported work to analyze and understand the performance of the MC3028 as it ages. Simulating this device is a challenging problem for including the coupled physics of detonation, shock propagation, and electromagnetic field generation and was not feasible prior to having the ASCI Red computer at Sandia National Laboratories (SNL).

We developed a comprehensive, three-dimension model of the MC3028. The simulation tool chosen was the EMMA code, which is based on the ALEGRA code being developed at SNL. ALEGRA is an arbitrary Lagrangian-Eulerian material dynamics computer code that emphasizes large deformations and strong shock physics. EMMA adds the capabilities to perform electromagnetic calculations based on a quasi-static approximation to Maxwell's equations and to model circuits. It includes models for ferroelectric materials that couple the stress and dielectric tensors through a set of electrostrictive coupling parameters.

We calibrated the computational model using data from experiments. Confidence in the predictive ability of the model was achieved through a verification and validation process. Simulations and an extensive parameter study provided a better understanding of the performance of the MC3028 as is ages and support the position that the MC3028 is expected to perform its intended function as it ages.

Level of Classification: *unclassified*

Keywords: *modeling, simulation, firing set, electromechanical, ferroelectric*

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[*] Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.