Modeling Initiation in Exploding Bridgewire Detonators

There is great interest in the dynamics of exploding bridgewire (EBW) performance and its role in the process of initiation in EBW detonators. We need to better understand the mechanism by which electrical energy stored in a fireset transforms into initiating energy within a high explosive, and how this mechanism is disrupted by changing materials and geometry.

This project uses LLNL's magnetohydrodynamic (MHD) code CALE to model the explosion of an EBW when placed in a circuit with a fireset. The models began as 1-D and have been generalized to 2-D, with the capability of including details due to aging, such as the growth of intermetallic compounds.

Project Goals

The project is complete at this time, having reduced to practice a first-principles-based approach to computational simulation of EBW performance. The goals of this project included: implementation of sufficiently accurate 2-D models for pure metal EBWs surrounded by high explosive; implementation of models that predict performance of aged systems; and preliminary validation of the MHD models in CALE at the energies of interest.

Relevance to LLNL Mission

This project has enhanced Engineering's toolset by producing techniques for evaluating performance margins in detonators, a capability critical to LLNL Stockpile Stewardship.

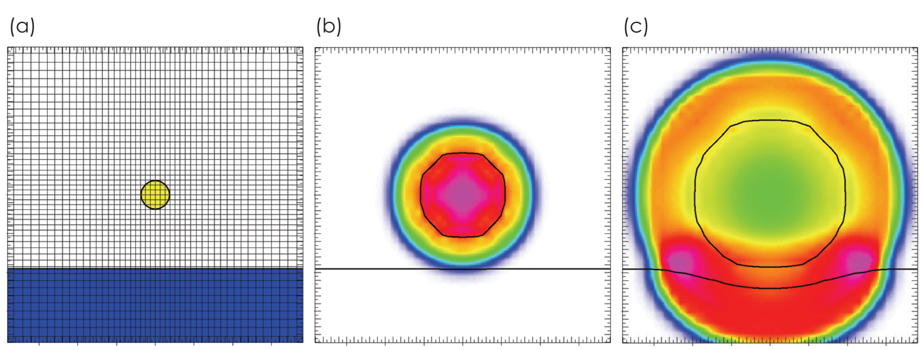

Figure 1. (a) Initial configuration of a 2-D axial model of a new gold EBW, showing mesh density and location of header (blue region). (b) As wire explodes, it sends a shock into the surrounding medium. Relative pressures predicted by the model from high (magenta) to low (blue) and zero (white) are shown at the instant the shock reaches the header. (c) By the time the shocked region doubles in width, the wire vapor has expanded and cooled, and the confinement and reflection provided by the header on the shock increases pressure in the magenta "pinch" zones.

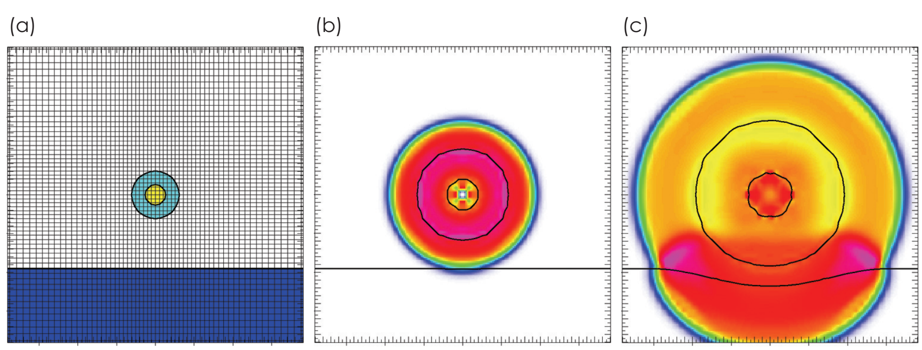

Figure 2. (a) Initial configuration of a 2-D axial model of an aged soldered gold EBW close to the solder mound. (b) The $AuIn_2$ layer heats and explodes first, followed shortly by the pure gold core. In this example, it takes 20% more time for the shock to reach the header, and at this instant, the highest pressure in the powder is reduced by 25% compared to normal (Fig. 1). (c) By the time the shocked region doubles in width, peak pressures in the powder above the wire and in the pinch zone near the header are both 20% less than normal.

Engineering Modeling and Simulation

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FY2005 Accomplishments and Results

In FY2005, 2-D models were created to better understand both longitudinal and axial aspects of EBW performance. A material model for gold-indide ($AuIn_2$) was introduced, based on our experimental studies to find this material's coefficient of thermal expansion (see reference 1). The explosive most commonly used with gold EBWs, pentaerythritol tetranitrate (PETN), has also been incorporated into our models.

Figure 1 shows an axial model of normal gold EBW burst, including header effects. The header provides confinement to the high explosive powder and reflects energy back toward the EBW, creating something like a Mach stem effect. Figure 2 shows a model of an aged soldered gold EBW, at similar stages, for comparison.

Figure 3 shows the effect of a large air gap, filling the space between the EBW and the header. Because of the expansion of the gold vapor into the gap space and an effective loss of confinement due to the gap, pressure intensities in the powder are reduced relative to normal. These are examples of the type of sensitivity and impact studies that this new modeling tool can provide.

The 2-D models are now also capable of evaluating square geometries, as in slapper-initiated detonators and exploding bridgefoil (EBF) (Fig. 4).

Due to problems experienced while fabricating specimens for model validation, the EBW and EBF models demonstrated are only partially validated at this time. The anticipated Engineering Cluster Tool will be able to create appropriate specimens for more complete model validation.

Related References

1. Saw, C. K., and W. J. Siekhaus, "Thermal Expansion of $AuIn_2$," *Scripta Materialia*, August 2005.
2. Chace, W. G., and H. K. Moore, Exploding Wires, Plenum Press, Inc., New York, 1959.
3. Maninger, R. C., "Predicting Time-of-Burst of Exploding Bridgewires from Thermodynamic and Electrical Properties," *Fourth Symposium on Engineering Aspects of Magnetohydrodynamics*, April 1963.

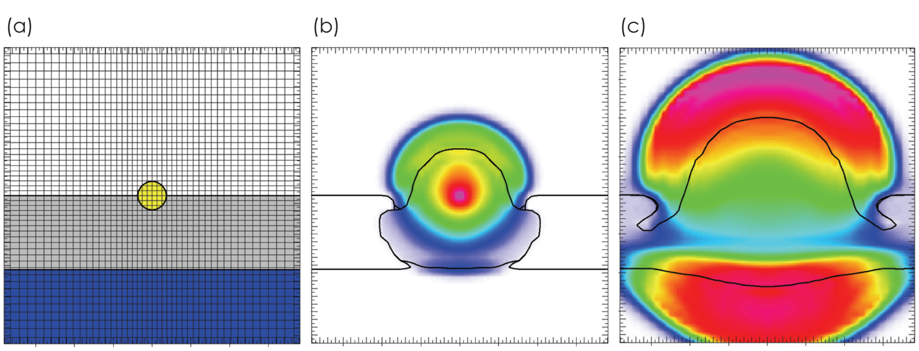

Figure 3. (a) Initial configuration of a 2-D axial model of a gold EBW with a significant gap between the powder and the header (grey region). (b) As the wire explodes, its vapor expands into the gap space, reducing its effect on the powder. It takes 5% more time to reach the header, and at this time peak pressures above the EBW are reduced by 25% relative to normal (Fig. 1). (c) By the time the shocked region doubles in width, peak pressures in the powder above the wire are 25% less than normal and the pinch zone near the header is nonexistent, due to the loss in confinement from the gap.

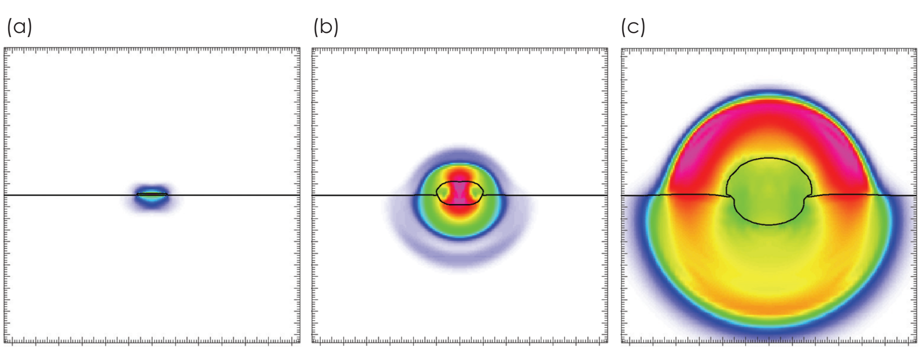

Figure 4. Very early in a 2-D axial model of an EBF. The very thin bridge is just beginning to vaporize. (b) Early in the explosion of the foil, the shock is planar near the centerline of the foil, transitioning to a more cylindrical geometry as the edge effects propagate inward from the sides. (c) Later in time, the shock in the powder is almost purely cylindrical in shape, again enhanced near the header.