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Malcolm Baldrige National Quality Award 2007 Award Recipient

Using Finite Element Modeling and Analysis to Advance 40mm Grenade Munitions

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

NDIA 2012

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Overview

- Non-Lethal flash bang detonation integrity models
- Non-lethal 1006 impact modeling
- One-Piece Body Design
- M433 OPB Staking
- M433 Band Swaging
- Base Plug Insertion & Crimping
- M550 Fuze Dud Investigation
- Rotating Band material evaluation
- Test barrel in-bore detonation for safety
- M430/M433 Warhead forming
- Warhead Detonation Structural Modeling

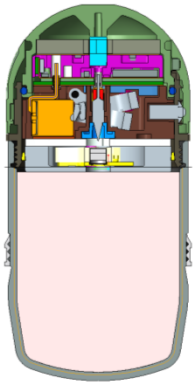
Flash-Bang structural failure

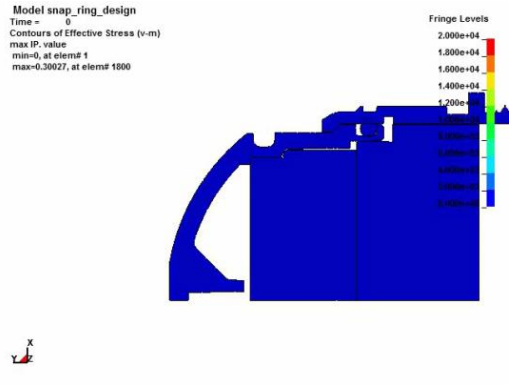
Engineering Challenge: During testing of prototype, undesirable structural failure occurred during flash-bang detonation.

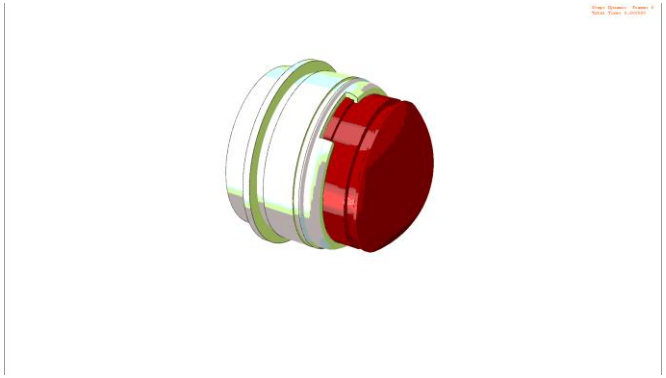
Analysis Focus: : Simulate the failure; use simulations to guide design changes to component to prevent failure.

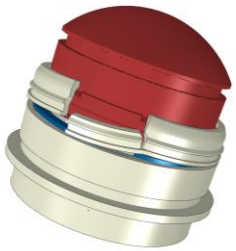
Modeling challenge: Determine loading conditions during detonation; material properties and material model approximations; identify level of model complexity required to meet objective

Summary of results: Simulations duplicated failure. Little iteration with testing required. Design modifications applied successfully negated failure mechanism, allowing projectile to remain intact after detonation.









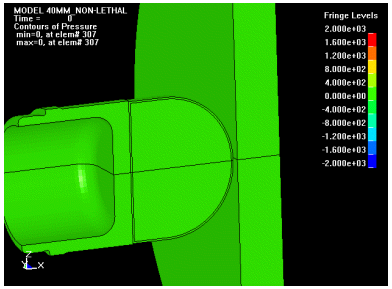
1006 impact pressures

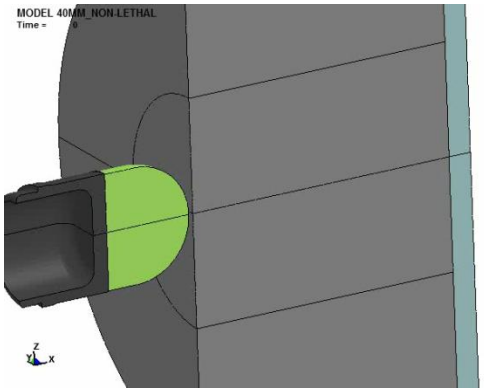
Engineering Challenge: Determine the Pressure across the surface at impact to aid in development of pressure-sensing material. Compare to non-lethal standards. Assist in projectile development where applicable.

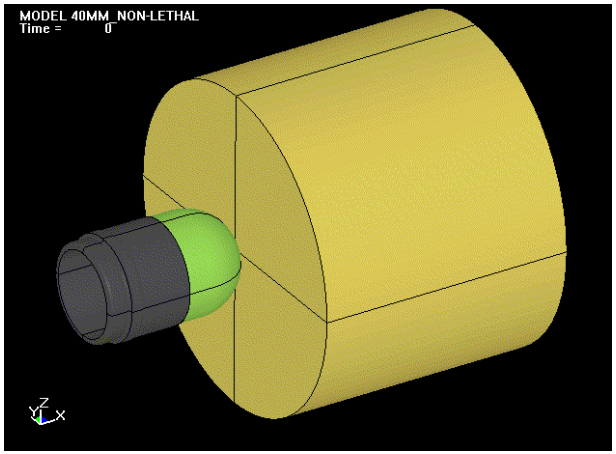
Analysis Focus: : Characterize foam and clay materials. Create impact simulations and compare to test data.

Modeling challenge: Determine optimal material model and material properties for foam and clay. Simulate response that correlates to test data without unrealistic "tweaks" to material properties

Summary of results: Simulations duplicated test data. Data taken from simulation aided projectile and test data development. Modeling techniques development in this effort used in numerous follow on efforts







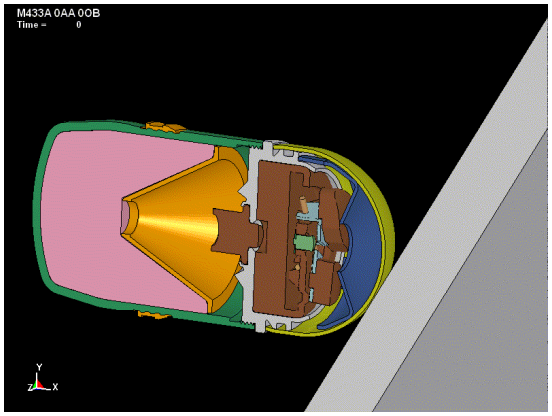
One-Piece Body Design

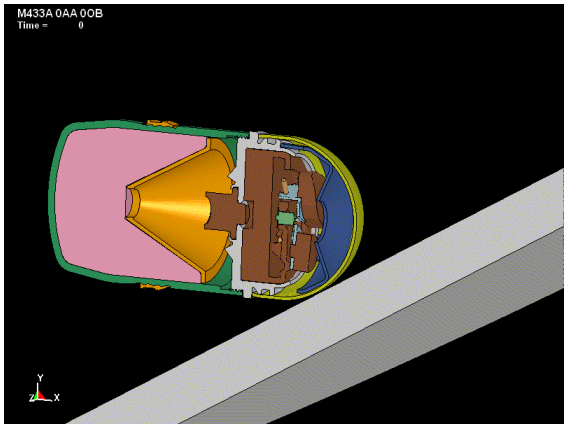
Engineering Challenge: Assist development cycle to explain dud-rate for new design and use models to explore geometry /material changes to improve design

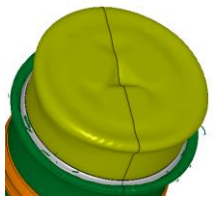
Analysis Focus: Impact model with special attention to modified regions of projectile and how they fail upon various impact's

Modeling challenge: Material properties at appropriate strain rates. Max/min tolerance of complex assemblies and other non-ideal conditions

Summary of results: Simulations duplicated test data. Data taken from simulation successfully aided projectile and test data development.







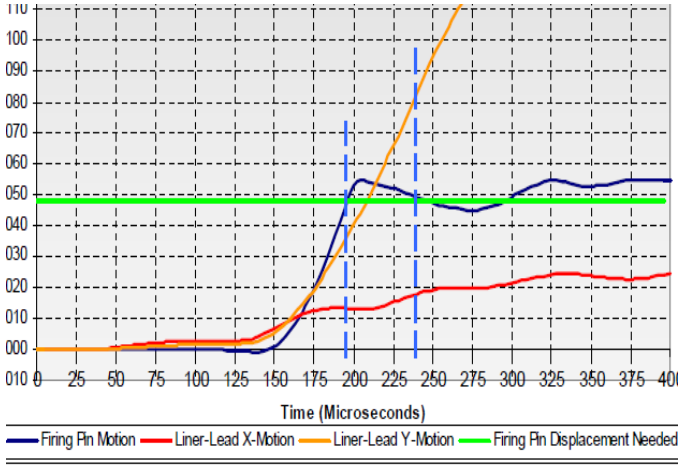


Figure 14. -60 Degree Obliquity Displacements

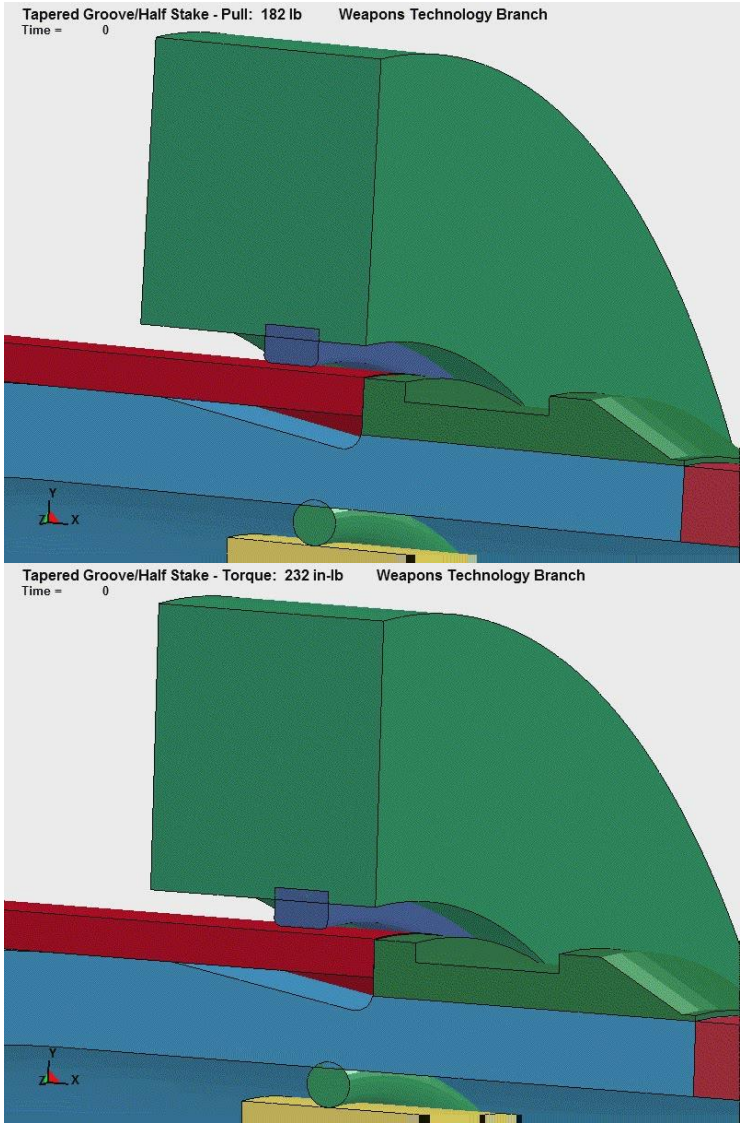
M433 OPB Staking

Engineering Challenge: Cartridge case must be crimped around projectile to certain pull force, torque, and leak requirements .

Analysis Focus: Crimp and/or stake different groove geometries in different ways to reduce number of actual parts needed for testing.

Modeling challenge: Many variations of grooves, crimps, stakes, and outputs result in extreme number of simulations. Special setup of analysis needed to make adding of different geometries easy without starting over. Torque measurements need special setup and disallow axisymmetric modeling.

Summary of results: Pull force mimics reality, but some tweaking needed to replicate torque values. Interest has been expressed in simulating leak test after staking.



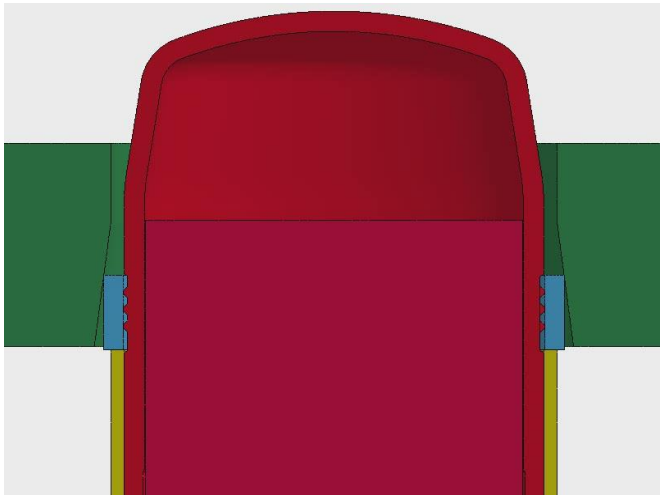
M433 Band Swaging

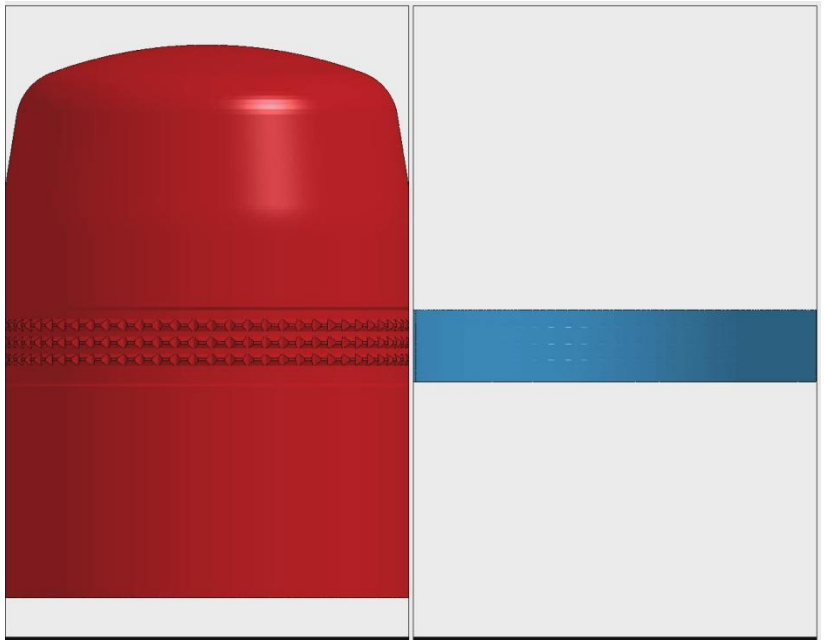
Engineering Challenge: Faster and easier swaging method for the opturating band for later testing on new band materials

Analysis Focus: Swaging process must be completed without tool failure. Allowing for the minimum force press needed.

Modeling challenge: The band is swaged around many knurls making axisymmetric simulations only useful for preliminary results.

Summary of results: Angle of swager does not alter force requirements significantly as it effectively just adjusts the speed of the swaging process. Extending the swager with a flat area is needed to keep the top of the band from spreading back out away from the projectile





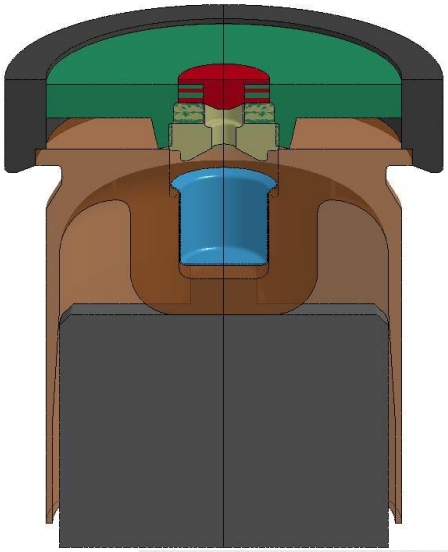
Base Plug Insertion & Crimping

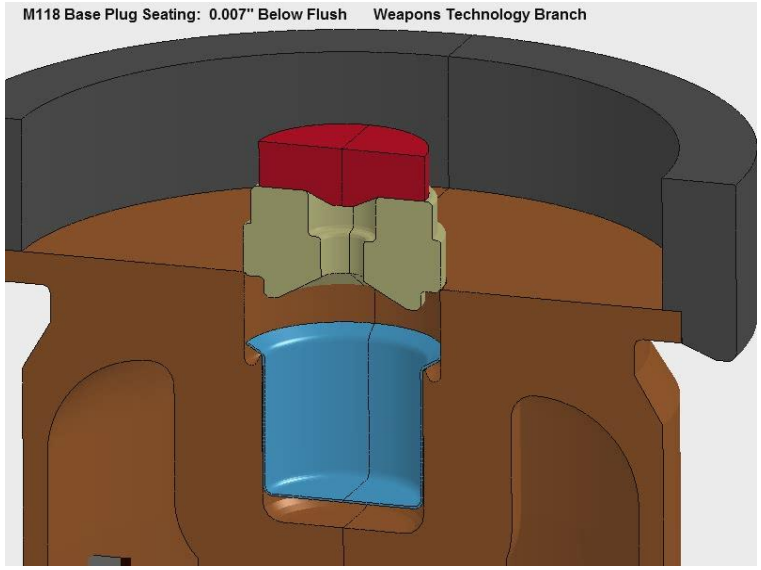
Engineering Challenge: 40mm Cartridge Case base plugs must withstand certain push-out requirements, without needing an extreme amount of force during manufacturing

Analysis Focus: The liner and plug are inserted with force measurements being taken. Then the force of pushing the plug back out is measured

Modeling challenge: Large deformation during crimping ensures the need for small element sizes.

Summary of results: The liner and plug can be inserted and crimped utilizing a standard crimping machine.





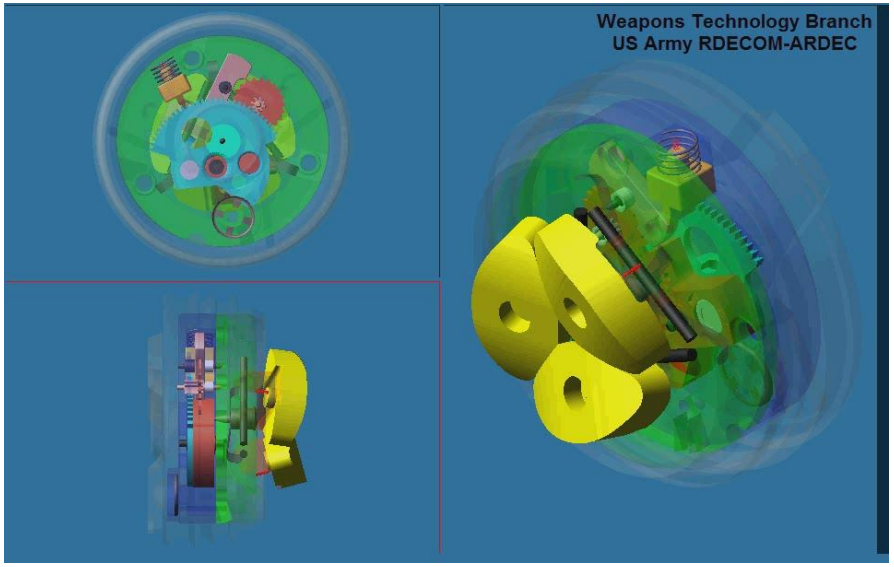
M550 Fuze Dud Investigation

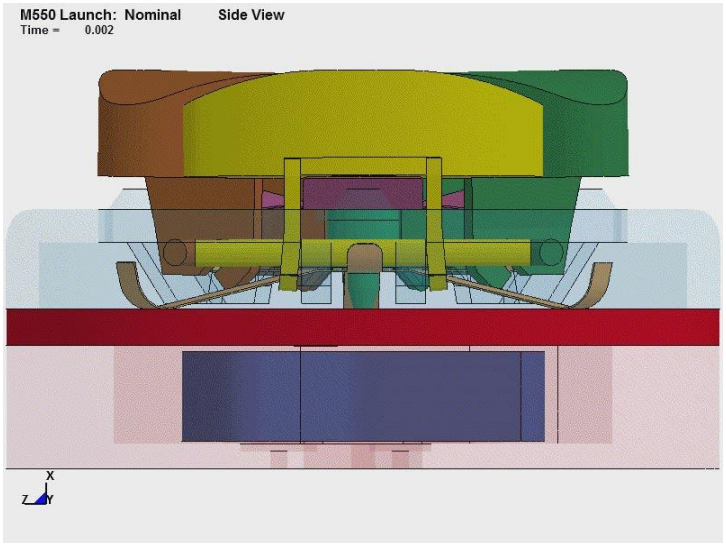
Engineering Challenge: The dud rate of the fuze in the M433 projectile has increased to unacceptable levels.

Analysis Focus: Rigid and flexible body analyses done to find causes of a non-functioning fuze

Modeling challenge: Many moving and contacting parts result in long run times. Simulations can only be done on situations that are thought of beforehand. Special spider springs need to be pre-compressed before launch.

Summary of results: The fuze functions when under all normal operating conditions. More cases need to be simulated to find the cause of a non-functioning fuze.





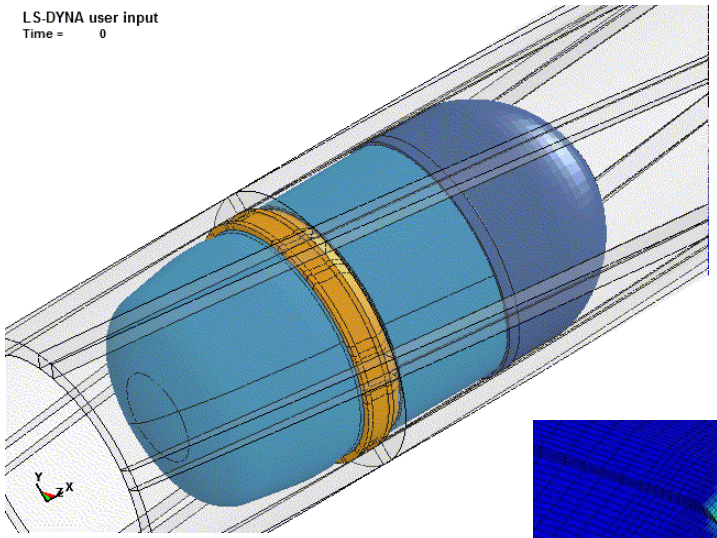
Rotating Band Material Evaluation

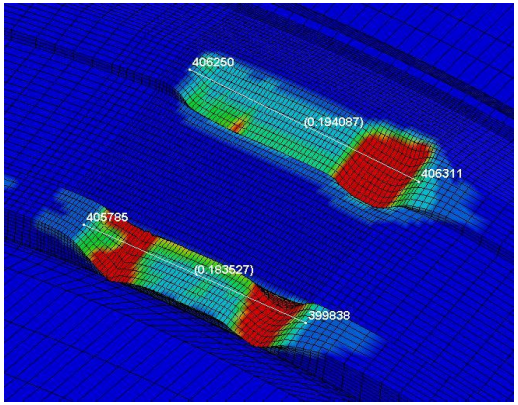
Engineering Challenge: Characterize resistance forces due to different rotating band materials

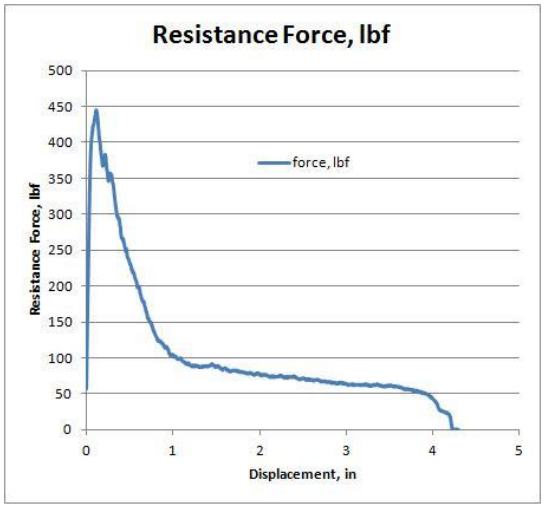
Analysis Focus: Launch model with attention to excessive band deformation implying slippages

Modeling challenge: Accurately characterize material properties and launch interactions

Summary of results: Simulations predicted greater degree of slippage in weaker bands; showed decrease in resistance forces







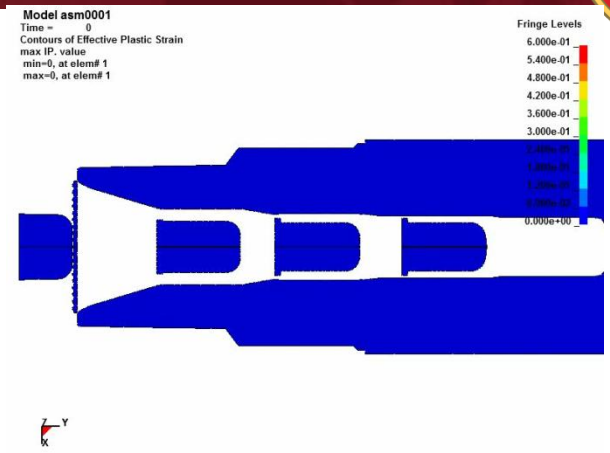
Warhead Forming

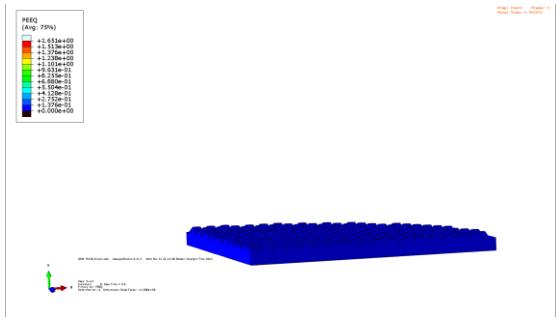
Engineering Challenge: Material limits exceeded, or nearly exceeded during warhead forming, causing weak-points that degrade the effectiveness of the warhead in certain detonation scenarios.

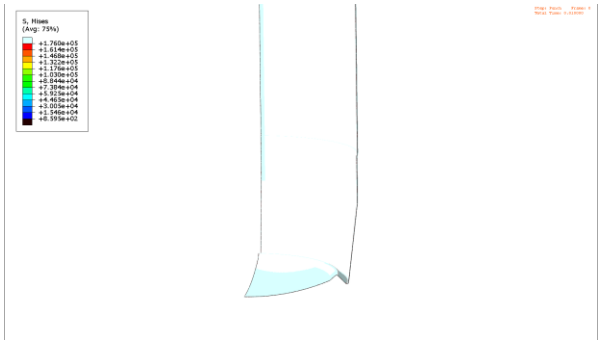
Analysis Focus: : Create simulations of the warhead draw process to evaluate the damage incurred during manufacturing and determine if geometry changes can overcome the issue.

Modeling challenge: Determine level of model complexity, symmetry and components necessary to extract adequate engineering info. Long simulations times due draw times. High mesh density due to complex geometry of embossing. Detonation of deformed geometry.

Summary of results: Simulations capture stress/strain relationship during manufacturing which aligns with failure modes. Work to optimize geometry is on-going







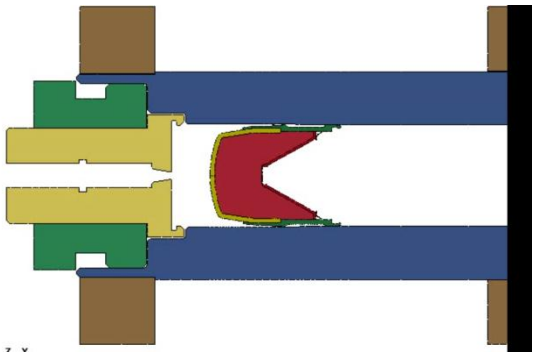
In-bore detonation results

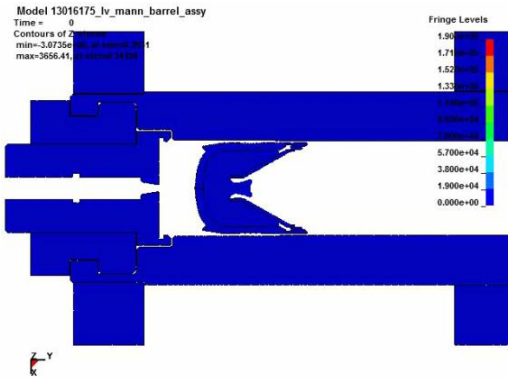
Engineering Challenge: Determine if an in-bore detonation will cause catastrophic material failure in the barrel or breach. Determine level of injury that may occur as a result.

Analysis Focus: : Model M433/M430 in various location and evaluate stress/strains imparted to test barrel and components. If fracture is apparent, estimate fragment mass/velocity and resulting “lethality”

Modeling challenge: Determine level of model complexity, symmetry and components necessary to extract adequate engineering info.

Summary of results: Simulations suggest barrel failure, but not catastrophic. Work is on-going to better estimate fragment danger.





$$\text{WallVelocity} := GC\cdot\left(\frac{1}{2}+\frac{M}{C}\right)^{\frac{-1}{2}} = 0.795 \quad \frac{km}{s}$$

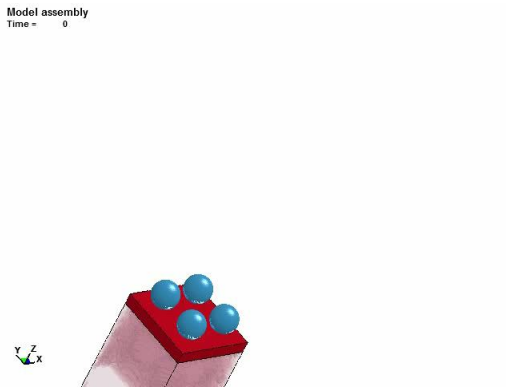
Detonation and structures

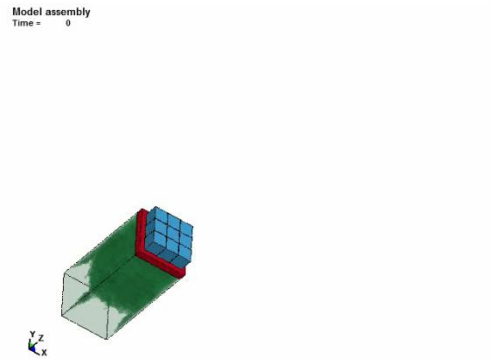
Engineering Challenge: Determine the amount of deformation and potential to fracture for “pusher plates” and pre formed fragments. Explore the trade space and optimize geometry, materials and explosive energy

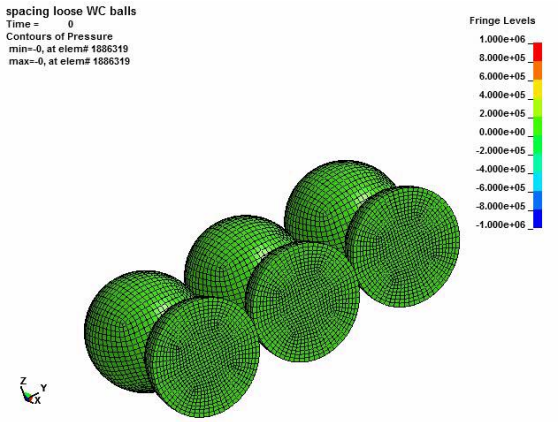
Analysis Focus: couple material testing with material model exploration to create models adequate for developmental use.

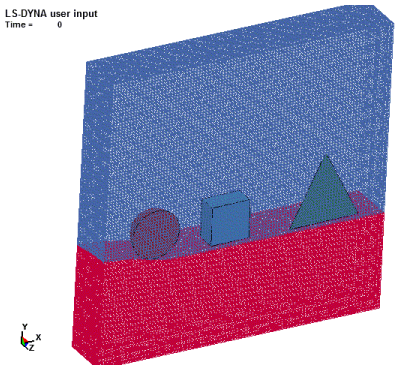
Modeling challenge: Determining fracture, or potential to fracture. Accounting for very high strain rates. Adequate Mesh density.

Summary of results: Simulations provide abundant quantity of engineering information useful for the development cycle. Fracture is roughly estimated, at best. Use models in concert with testing to evolve models and quality of design.









Summary

- M&S being successfully used to:
  - Reduce number of prototypes required
  - Reduce testing costs*
  - Reduce project completion time*
  - Improve quality of end product

*Must balance M&S capability/cost vs. testing capability cost. M&S is usually, but not always the most effective method if initiating and supporting design efforts.

Questions

Questions?