If you can't get a bigger target...

Design, Analysis and Testing of a 5.56mm Polymer Cartridge Case

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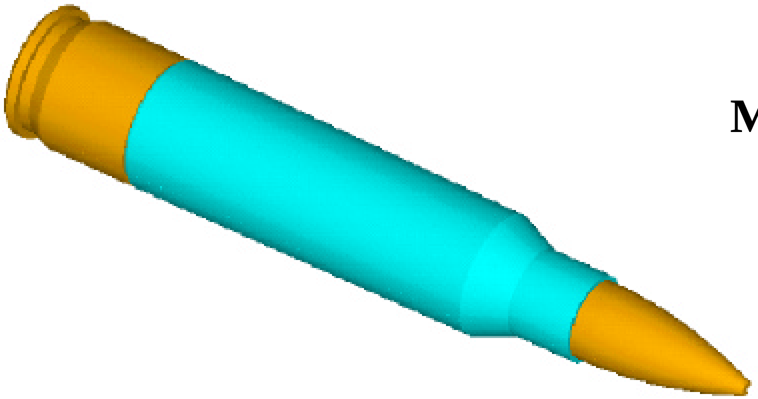

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Outline

- Introduction
- Goals/Objectives
  - Product
    - Benefits
    - Design
    - Material
  - IB/Modeling Analysis
- Polymer Cartridge Case Analysis & Results
  - Analytical Approach
  - Modeling
  - Results/Conclusions
- Project Status
  - Additional Studies
  - Testing/Interest

Goals/Objectives

- Polymer-Cased Cartridge
  - Function in Existing Weaponry without Modification
  - Meet Objectives of Standard Brass Specification
  - Provide Cost Effective Transition to Production
  - Serve as "Bridge to the Future" for Lightweight Soldier Initiatives
    - Immediate Savings while Longer-Term Development Items Mature

Polymer Case Benefits

- Directs More Energy to Projectile, Reducing Propellant Requirement to Obtain Comparable Ballistics
- Reduces Heat Transference to Chamber (Natural Insulator)
- Reduces Muzzle Flash
- Provides “Dimensional Memory” for Consistent Weapons Feeding
  - Distortion During Transportation/Handling has No Impact on Chambering/Firing
- Reduces Case Rupture Effect
  - Case Easily Removed Without Damaging Weapon
- Reduces Weight Load on Soldier/Aircraft
- Reduces Manufacturing Cost with Simplified Manufacturing Process
  - Requires No Sealant at Projectile/Case Interface; Self-Sealing Production Process

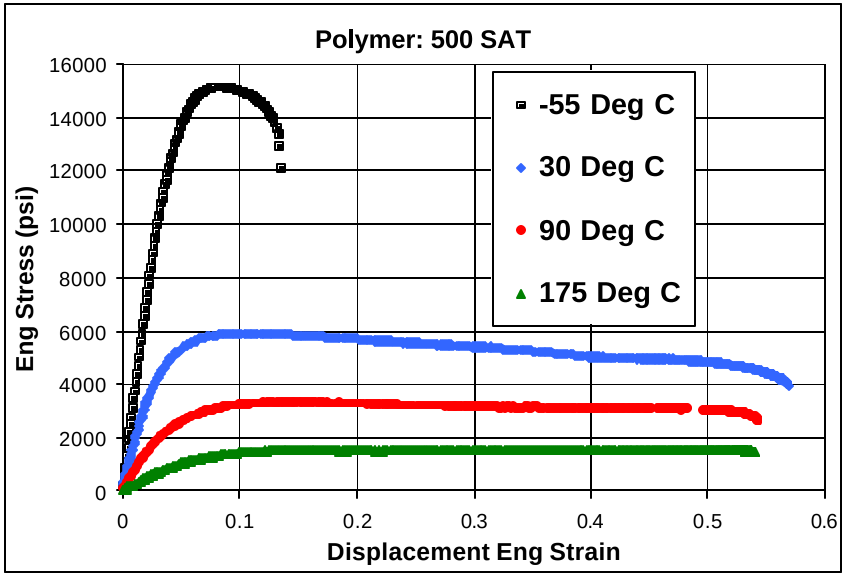
Polymer Case Design

- Design Goals
  - Lightweight Materials that Meet Performance Requirements
    - Minimal "Non-Qualified" Component Materials
  - Manufacturing Process that is Efficient and "Eco-Friendly"
- Current Design Components (5.56mm Cartridge)
  - Zytel Nylon 612 Polymer (Modified - 4th Generation) Cartridge Case
  - M855 62 gr. Full Metal Jacket Boat Tail (FMJBT) Projectile
  - Alloy 260 Cartridge Brass Base Cap
  - No. 41 Military Primer
  - Primer Sealant, High Viscosity Purple
  - WCC 844T Propellant

Polymer Material

- Material Characterization/Accelerated Aging* Studies
  - Plans Developed by NSWC-Dahlgren, Texas A&M, and Amtech, Inc.
  - Testing Conducted by Texas A&M
  - Analysis and Report Written by Texas A&M – Reviewed by DuPont
  - Results Provided to Arrow Tech Assoc.

Stress-Strain Curve



Studies:

- Include DAM (Dry As Molded) and Saturated Test Samples
- Vary Across Contracted Temperature Ranges (Both Storage and Operational)

* Accelerated Aging Study in Progress.

Goals/Objectives

- IB/Modeling Analysis
  - Validate Actual Testing Results
    - Provide Scientific Basis for Demonstrated Performance
  - Facilitate Expansion into Larger Caliber Cartridges
    - Project Feasible Caliber Range
    - Accelerate Incorporation of Design/Component Improvements

Analytical Approach

Perform Modeling and Analysis to Ensure Structural Integrity

- **Analytical Issues:**
  - Brass & Polymer Material Description
  - Chamber Pressure vs. Ammo Conditioning Temp.
  - Case Mouth vs. Chamber Pressure
  - Bolt Mass & Stiffness

- **Case & Chamber Interaction**

Analysis Goals

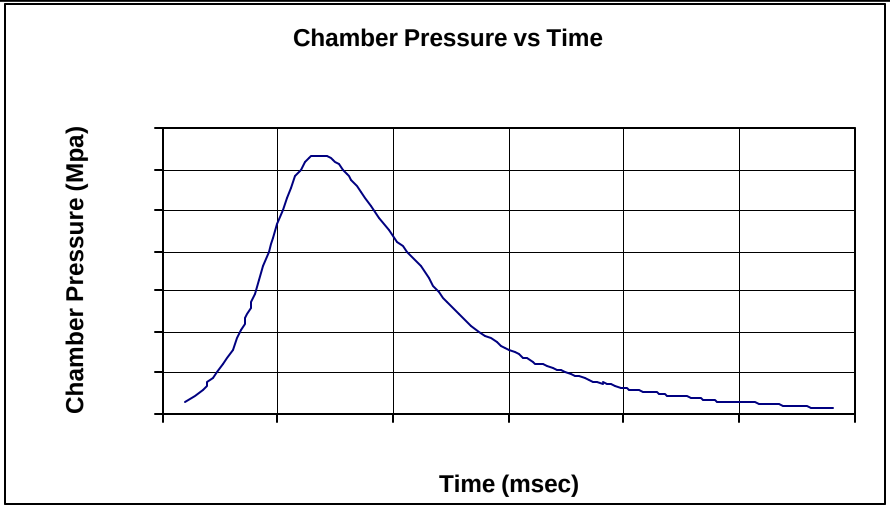
- Interior Ballistics Modeling (from test data)
- Case/Chamber Modeling and Analysis
  - Brass (nominal dimensions at hot, ambient, & cold)
  - Polymer (nominal dimensions at hot, ambient, & cold)
  - Dimensional Parametric Studies
  - Investigate Several Gun Chambers: M4, M16A2 & M249

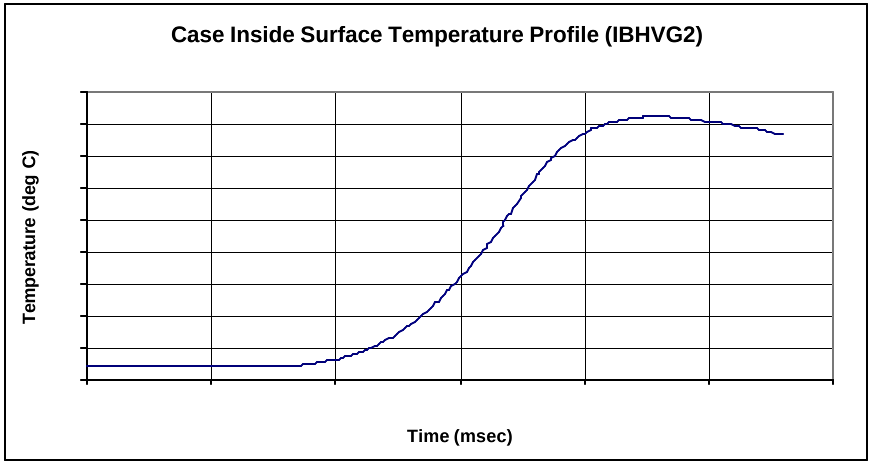
Analysis Approach

- CASAS: CASe Analysis System
  - Elastic-Plastic, Thermal, Dynamic Solution
  - Models the 5 Phases of Case/Chamber Interaction
    - Initial Conditions (temperature, tolerances, etc.)
    - Propellant Ignition
    - Pressure Load Increase
    - Elastic Recovery
    - Residual Interference (or clearance)
  - Evaluate Peak Material Strain and Peak Bolt Loads
  - Lumped Parameter FEM Model
  - Alternative to General Purpose FEM Programs
  - Ideal for Performing Trade-off Studies During Design

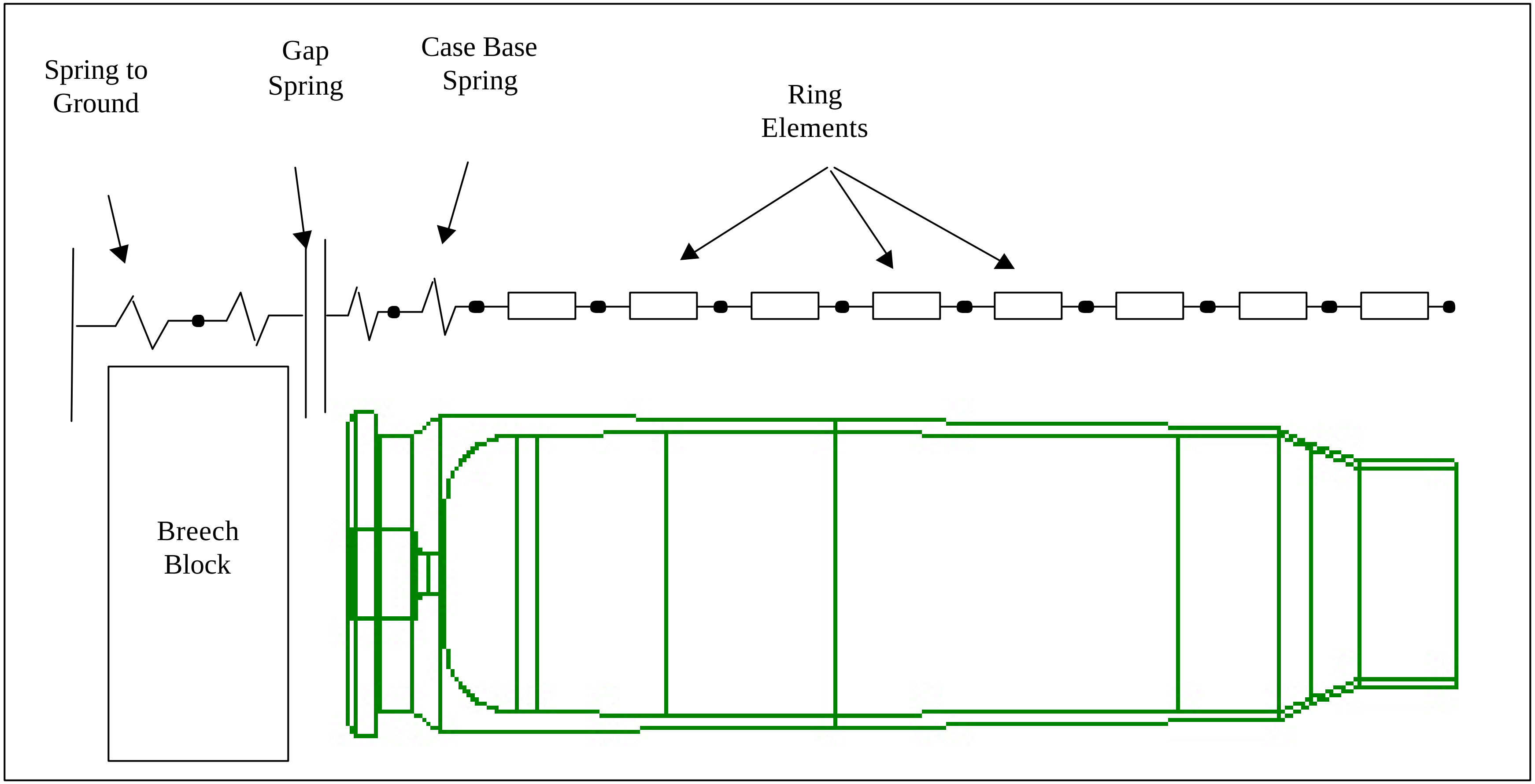
Data Requirements

- Forcing Functions
  - Pressure (P-T Curve)
  - Temperature
- Material Properties
  - Cartridge Case
    - Density, Modulus
    - Diffusivity
    - Coeff. of Thermal Expansion
    - Stress-Strain Curves
  - Chamber
    - Modulus
    - Diffusivity
  - Case/Chamber Interface
    - Static Coeff. of Friction
    - Dynamic Coeff. of Friction



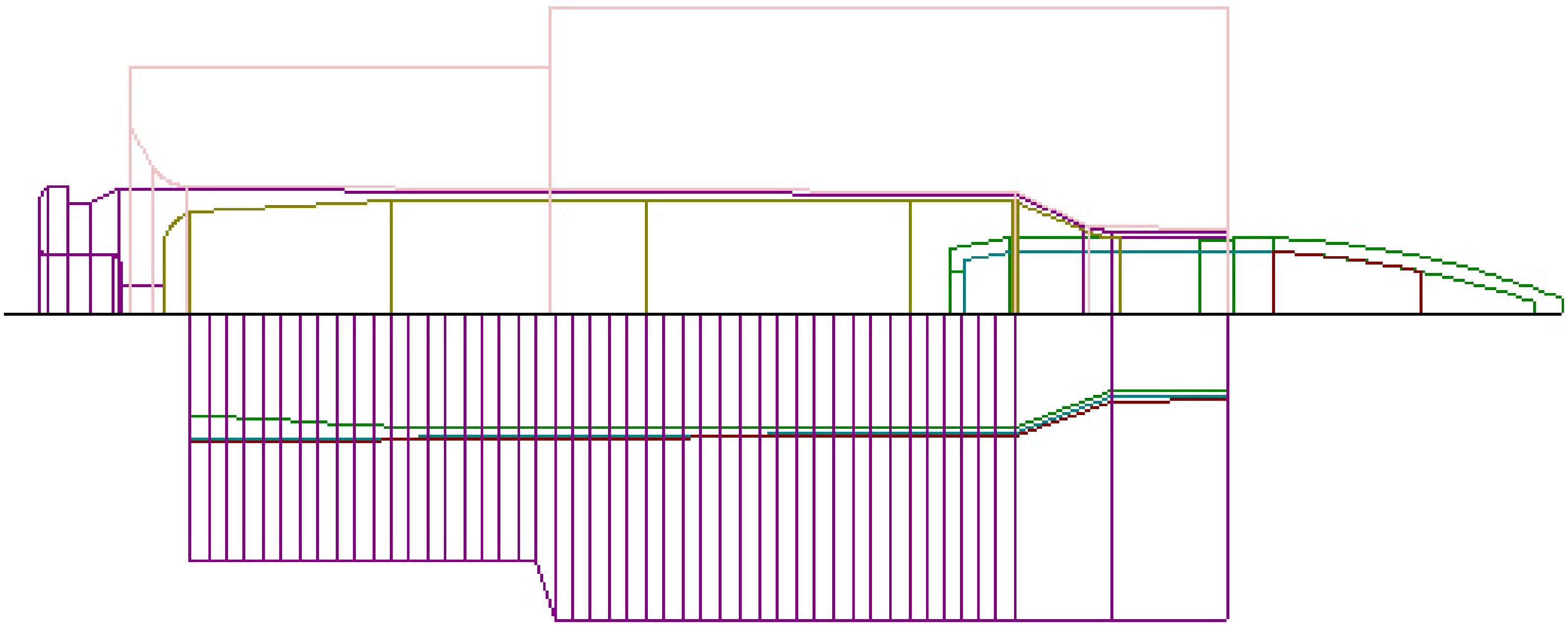


Lumped Parameter Model

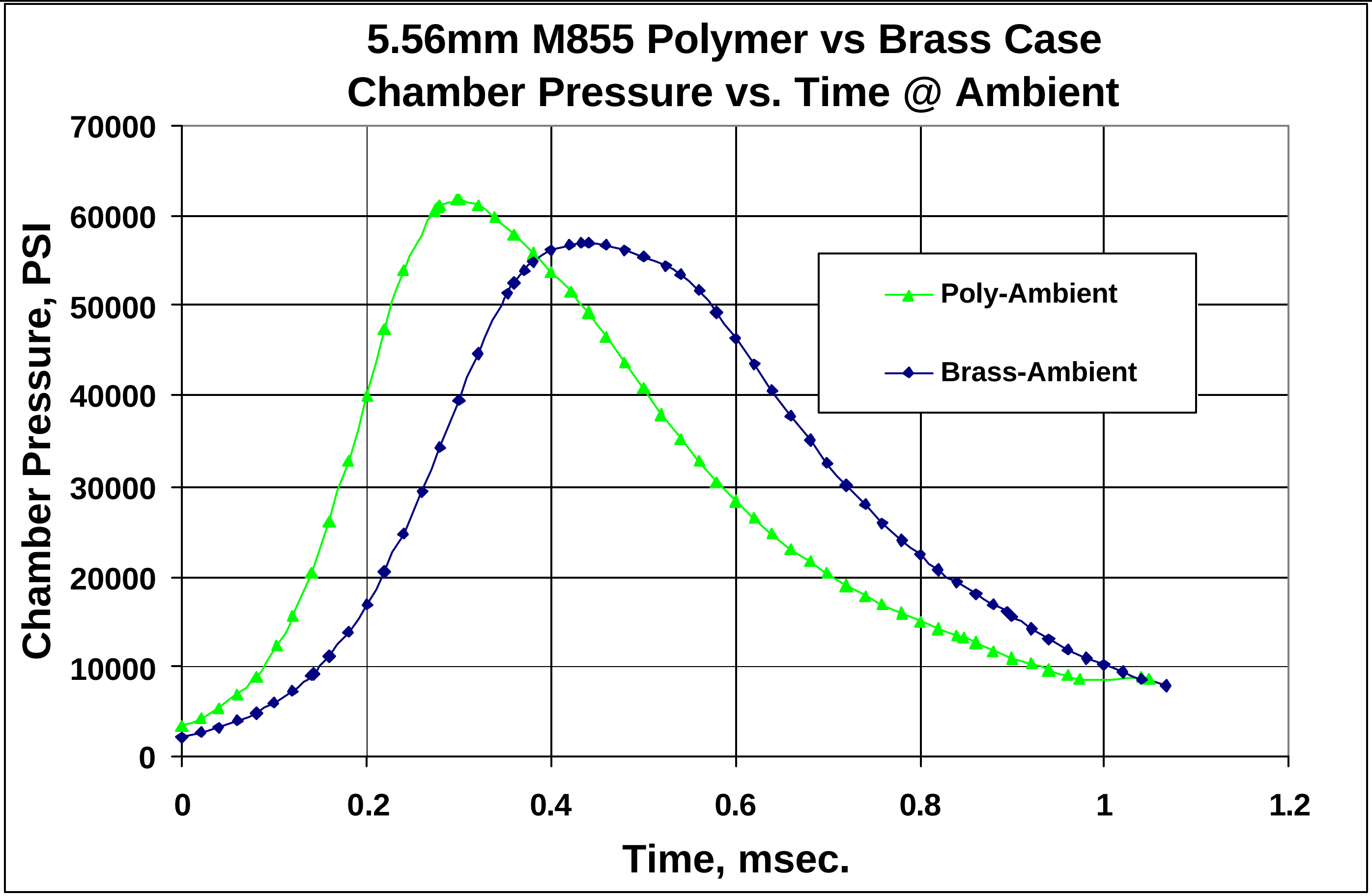


Lumped Parameter Model

Lumped Parameter Model of the Gun Chamber
and the Cartridge Case is Generated
Automatically within PRODAS



Analysis Results - Ballistics



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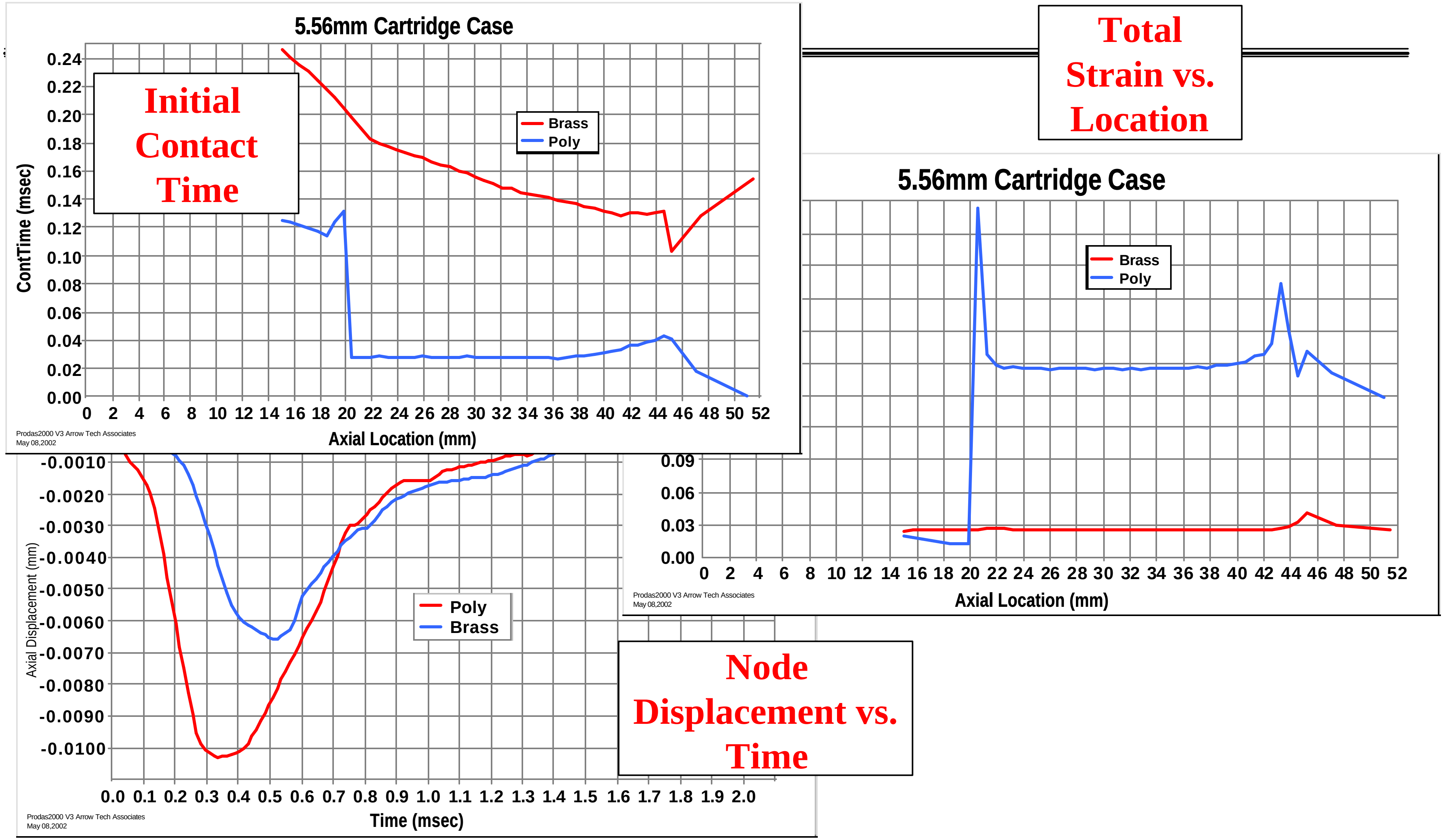
Analysis Results



Analysis Results – Total Strain

Case/Condition	*Peak Total Plastic Strain (in/in)*	*Time at Peak (msec)*	*Elastic Strain (in/in)*	*Total Strain (in/in)*	*Percent of Ultimate Strain*
Brass-Cold	0.044	1.235	0.004	0.048	40%
Brass-Ambient	0.044	1.060	0.004	0.048	40%
Brass-Hot	0.049	1.034	0.004	0.053	44%
Polymer-Cold	0.275	1.544	0.02	0.295	52%
Polymer-Ambient	0.284	1.503	0.02	0.304	53%
Polymer-Hot	0.313	1.503	0.02	0.333	58%

Analysis Results – Dimensional Strain

Case Scenario	*Temp. Condition*	*Axial Plastic Strain (in/in)*	*Total Strain (in/in)*	*Percent of Ultimate Strain*
Min Case/Min Cham	Ambient	0.146	0.341	60%
Min Case/Max Cham	Ambient	0.258	0.477	84%
Max Case/Min Cham	Ambient	0.099	0.274	48%
Max Case/Max Cham	Ambient	0.099	0.275	48%
Min Case/Max Cham	Hot	0.273	0.529	93%
Nominal	Ambient	0.118	0.304	53%

Analysis Results – Total Plastic Strain

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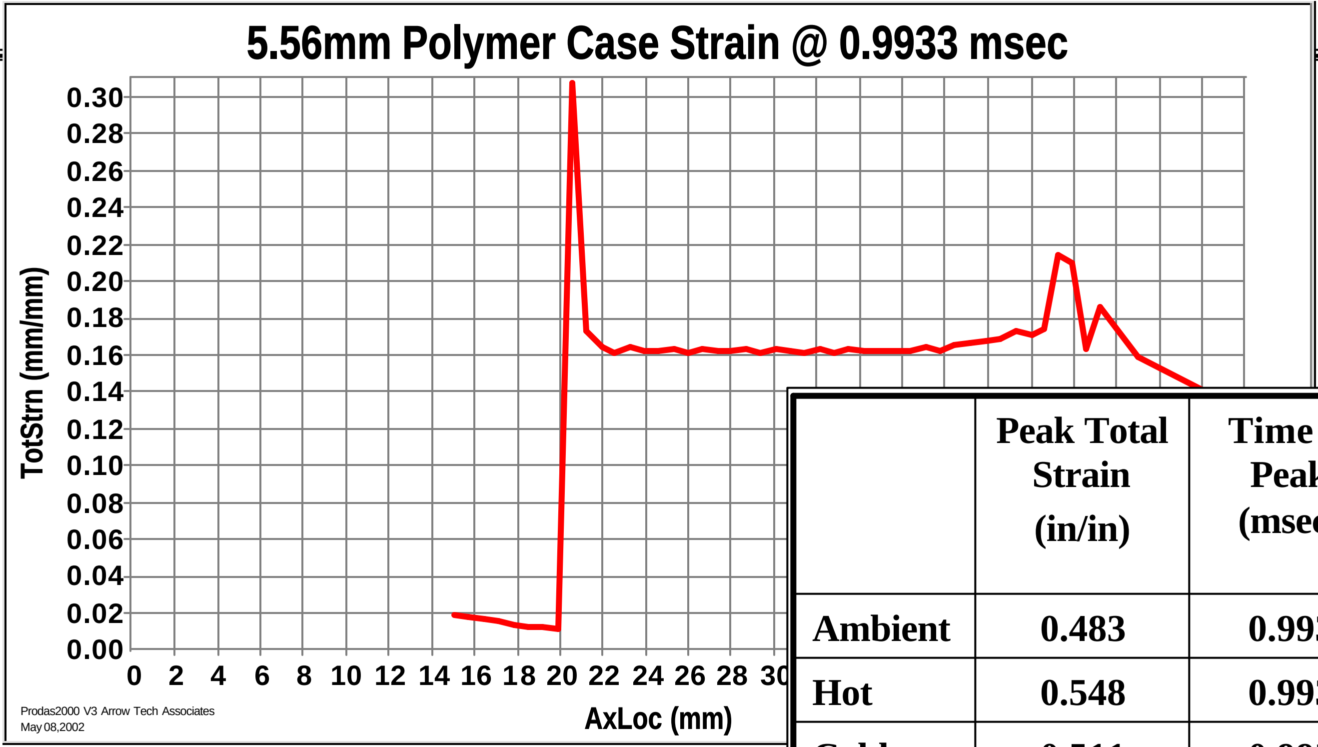

	Peak Total Strain (in/in)	Time of Peak (msec)	Axial Location (from base of PRODAS model) of Peak (in)
Ambient	0.483	0.993	0.782
Hot	0.548	0.993	0.782
Cold	0.511	0.993	0.782

At Ambient:

Total Elastic Strain (0.033) + Plastic Strain (0.483) = Total Strain (0.516)

Worst Case: Total Strain of 0.516 is approx. 90% of ultimate strain (0.57)

Analysis Results - Summary

- IB/Modeling Analysis of Amtech 5.56mm Polymer Case
  - Design Indicated as Structurally Adequate, with Peak Total Strain Yielding Sufficient Margin to Ensure Function Without Separation at All Temperature Conditions
    - At Nominal Dimension, the Amtech Polymer Case Performs at 52-58% of Ultimate Strain; Worst Case ~ 90% of Ultimate Strain
  - Less Interior Ballistic Variation over Temperature Range than Brass Case
  - Lower Total Impulse Delivered than Brass Case
  - Lower Heat Transfer to Chamber than Brass Case
  - Lower Initial Extraction Force than Brass Case

- Model Validates Demonstrated Testing Performance

Project Status - Analysis Studies

- Additional Studies
  - 7.62mm Initial Study Complete
    - Scaled Up Simulation Model Predicts Actual Testing Results
    - Design Indicated as Structurally Adequate, with Peak Total Strain Yielding Sufficient Margin to Ensure Function Without Separation at All Temperature Conditions
  - 50 cal. and Larger Calibers to be Studied as Project Progresses

Project Status – U.S. Military Testing

- Amtech 5.56mm Polymer-Cased Ammunition
  - Passed Final Pre-Qualification Screening Test Conducted for Office of Naval Research (ONR) Contract
  - Passed Safety Certification Testing Conducted by Aberdeen for USSOCOM
    - Cartridges Procured to Begin Initial User Evaluation
  - Scheduling Pre-Qualification Test for ARDEC at Picatinny Arsenal (Standard LAT + Additional Tests)
    - Successful Test Results to be Followed by Army Pre-Production Qualification Testing