Fuze Simulation

49th Annual Fuze Conference
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Seattle, WA
Background

- History of consulting on problems/designs of fuze systems
- Involved in numerous failure analyses regarding fuze performance
- Experience has shown us that proper analysis can preclude problems and/or solve issues that arise after failure to conduct proper analysis
Typical Fuze Problems

• Intermittent fuze “Failure to Arm” at extreme conditions

• Under Design: Fuze intermittently fails to survive and/or arm
  • Increases program cost, risk, & schedule
  • Design-shoot-fix is costly

• Over Design: Fuze is heavier / larger / costlier than required
  • Large fuze volume claim reduces warhead effectiveness
  • Adversely affects range, time of flight, lethality
Simulation Solution Options

• “General Purpose” Modeling programs (e.g. Matlab)
• “Specialized Program” with custom written I/O & analysis for this particular fuze.
• “FuzeSim” Program w/ custom analysis & PRODAS I/O Environment
Flight Simulation

• Data on Rocket Firings:
  – Motor Function of conditioning temp
  – “Round-Round” variability

• Simulate rocket flight motion via BF 6 DoF trajectory code.

• Atmospheric variations easily assessed
Environment Definition

• Projectile motion / Acceleration environment from Trajectory Simulation
• Location of Fuze on Rocket
Simulation of Mechanism in Flight

• Mechanism EoM’s
• Rocket Motion
• Variable Thrust, Atmosphere, Mass, etc.

• Assess Arming analytically at extremes of both mechanism and environment
Fuze Arming Delay Simulation

Fuze with Spin Activated Flyweight Second Safe Arming Simulation
Launched at 15,000ft Altitude & 80 Knot Aircraft
Other Fuze Environmental Issues

• Gun Launched Projectiles:
  – In bore dynamics
    • Longitudinal
    • Lateral
    • Rotational
  – External Dynamics
    • Yaw/Pitch Motion
    • Blast Field
    • Sabot Discard
In Bore Dynamics

- Balloting analysis using lumped mass and finite beam elements models of Projectile & Gun Tube
- Simulated or measured Pressure-Time history
- Catalog / data rifling twist vs. travel
- Monte Carlo initial conditions
- Statistical Output
If you Can't Get a Bigger Target...

Projectile & Gun Tube Models

- Tube Geometry
  - Tube Lumped Mass & Beam Element Model

- Projectile Geometry
  - Projectile Lumped Mass & Beam Element Model

- Aft Bourrelet & Contact Spring
- Fwd Bourrelet & Gap Contact Spring

- Monte Carlo draw of initial conditions ensures mean and sigma of in bore environment are determined
Gun Tube Motion

- Motion in response to gravity droop?
- Motion in response to bore centerline curvature?
- Interaction between Projectile and Gun Tube?
If you Can't Get a Bigger Target...

Projectile Motion In Bore

- In bore transverse motion
Acceleration Environment

- Longitudinal Acceleration
  - Simulated vs. Measured.
- Lateral Acceleration
  - Mann Barrel vs. Tactical Barrel
- Rotational Acceleration
  - Twist vs. Travel
  - Forcing cone wear (Torsional Impulse)
If you Can't Get a Bigger Target...

Peak Pressure & Longitudinal Acceleration

- Muzzle Velocity, Peak Pressure & Time to 5-95% Pmax Matched
- Startup dynamic <5 msec. not simulated
- Causes 6% increase in impulse before Pmax, drives subsequent structural dynamics

Charge Pressure vs. Time

**Simulation**

**Measured**
Lateral Acceleration

- Peak Lateral Accel higher in Mann barrel
- Interaction of Projectile and flexible barrel
Rotational Acceleration

- Function of P-T History, Rifling Twist, Rifling Condition
- Forcing cone wear causes "Torsional Impulse" prior to Pmax
- Mechanical S&A must be designed to survive
Flight Simulation & Correlation

- Lateral Accels due to launch & flight dynamics
Conclusions

• Fuze Mechanism can be quickly modeled
• Mechanism performance in extremes of arming envelope can be assessed
• Improved understanding of the role of statistical variability vs. environment in arming.
• Improved understanding of in-bore and free flight environment extremes.
• Applicable for both rocket and gun launched projectiles