55th Annual Fuze Conference
Fuzing‘s Evolving Role in Smart Weapons

Generation and Measurement of Long Duration High-g Acceleration Profiles

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# OUTLINE

- **Introduction**
  - Need for Test Methods

- **Generation of Long Duration Transients**
  - EMI Defined-Long-Duration Shock Test

- **Application**
  - Choice and Test of Electronic Components

- **Measurement of Long Duration High g-Acceleration Profiles**
  - Penetration of Concrete

- **Summary**
Motivation
Smart Weapons with Penetration Capability

- High-g hardened fuzing
  - Large warheads
  - Upcoming: Smaller calibers as for precision guided munitions with moderate effect
    $a_{\text{max}} > 100,000 \text{ g}$
    \[ \Rightarrow \text{the smaller the ammunition, the bigger the acceleration} \]

- No manufacturers specifications available for electronic parts for high-g-regime
- Inexplicable system failures in the field

\[ \Rightarrow \text{need for reliable, cheap high-g-test methodology} \]
Required Test Methodologies for Sub-Scale Survivability Test

Fuze-Conference 2010:
D. Hayles, DTRA : Notional Shock Spectrum

technical requirement:
\( v_{0, \text{DUT}} > 100 \text{ m/s} \)

Photo Courtesy of AFRL/RWMF
EMI Defined-Long-Duration (DLD) Shock Test

- High initial velocity of actuator
  \[\Rightarrow\] long duration \textit{and} high amplitude load profiles

- Numerically tailored compression body
  \[\Rightarrow\] quantitative load profile estimation
  \[\Rightarrow\] new load regimes reproducible accessible

- Experimental validation by g-rec or PDV* measurements

\[\begin{align*}
\text{Example: } & 30.000 \, \text{g, } 800 \, \mu\text{s} \\
& - \text{Numerical prediction: movement of center of gravity} \\
& - \text{Measurement inside sample holder}
\end{align*}\]

*PDV: Photonic Doppler Velocimetry
EMI Defined-Long-Duration (DLD) Shock Test

- Current R&D-setup:
  - $m_{(\text{Device Under Test})}$ up to 200 g
  - $\varnothing < 34$ mm,
  - $l = 100$ mm

- If needed: Device under Test electrically connected
- Low temperature experiments (-46 °C) possible
- Modest cost
- Extension to spinning systems is under way

Exemplary sample holder

Example: 80.000 g oscillator-Test

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Exemplary sample holder

Example: 80.000 g oscillator-Test

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EMI - DLD - Shock Test

Comparison
- Experimental Data (50 kHz filtered)
- Numerical Simulation

- movement of center of gravity
Experiments were conducted in cooperation with industry partners and used for product development.

Experiments validated by

- **exp**
  - acceleration measurement or Photonic Doppler Velocimetry
- **sim**
  - numerical Simulation and high-speed Video
Application
Choice and Test of Electronic Devices

Device behavior upon high-g-loads:
- Intended function
- Disintegration of the device
- Malfunction only during load

⇒ DLD-Shock-Test with electrical access to relevant device properties during load

Example: Capacitor 1

⇒ intended function
Application

Choice and Test of Electronic Devices

Device behavior upon high-g-loads:
- Intended function
- Disintegration of the device
- Malfunction only during load

⇒ DLD-Shock-Test with electrical access to relevant device properties during load

Example: Capacitor 2
- (Reversible) effect only during load!
- Pre- and post-mortem results could be misleading

Approach / solution:
- Usage of different devices, or device technologies
- Improved engineering concepts
Application g-rec
Measurement of Long Duration High-g Acceleration Profiles

Concept

- Autonomous digital data recorder with shock accelerometer
- Resistant to high accelerations and decelerations (> 100,000 g, Ver. a)
- PC based data retrieval after projectile recovery

modular assembly:

Plug connector data extraction

2 versions:  a) hard-wired version

b) programmable, based on microcontroller
Application
Measurement of Long Duration High-g Acceleration Profiles

- Investigation of penetration processes
- Movement of the center of gravity
- Characterization of mechanical properties of HE during impact conditions

- Stand alone data recorder for harsh environments
- Measurement tool for fuze systems during impact

- Investigation of interior dynamic of penetrators
  - Study of mechanical wave propagation and resonances
  - Damage mechanisms, …

Simulation: "g-rec 32mm geschottetes Ziel 03.si3"
Concrete Penetration Measurement of Long Duration High-g Acceleration Profiles

36 mm - penetrator equipped with g-rec:
Gun launch (powder cannon) \( v_0 = 600 \text{ m/s} \)
Application
Concrete Penetration
Measurement of Long Duration High-g Acceleration Profiles

$\nu_0 = 600 \text{ m/s}$
- raw data
- 10 kHz filter

Impact

$\nu_0 = 600 \text{ m/s}$
- raw data
- 10 kHz filter

© EMI
Application
Measurement of Long Duration High-g Acceleration Profiles

Experiments with 60 mm projectiles

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Projectile and sabot, projectile: cal. 60 mm

© EMI

Concrete Penetration

150 mm-Facility, Ernst-Mach-Institute, Germany
Application

Concrete Penetration

Measurement of Long Duration High-g Acceleration Profiles

Interpretation after experiment, no real time processing.

caliber: 36 mm

caliber: 60 mm

\[ v_0 = 600 \text{ m/s} \]

\[ a_{\text{max}}, 36 \text{ mm} \text{ more than two times higher than } a_{\text{max}}, 60 \text{ mm} \]
Summary

- EMI-DLD-Shock Test
  - Powerful test-method that covers interesting high-g-load and long duration pulse regime
  - Reproducible lab-test at moderate costs

- Application of DLD-Shock Test: behavior of capacitors during high-g-load

- Measurement of long duration shock pulses with autonomous data recorder
  - g-rec: versatile and robust measurement-tool
  - Medium caliber concrete penetration at high velocities
    ⇒ the smaller the ammunition, the bigger the acceleration
Thank you for your Attention!
Questions?

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