NEW METHODOLOGY FOR SIMULATING FRAGMENTATION MUNITIONS

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Fragmentation Modeling

Outline

• Introduction
• Background
• Modeling Methodology
• Natural Fragmentation
• Preformed Fragmentation
• Conclusions
Fragmentation Modeling

Introduction

• **TACOM-ARDEC Warheads**
  - Long history of warheads design
  - Technology development
  - Application

• **Fragmentation Ammunition Requirements**
  - ALACV, OCSW, OICW, M203 upgrade
  - Lightweight ammunition
  - Lethal fragmentation, various approaches
Fragmentation Modeling

Background

• **Natural Fragmentation**
  – Limited lethality due to poor size distribution
  – Good structural characteristics (G load)

• **Preformed and Scored Fragmentation**
  – High lethality potential
  – Reduced structural integrity, efficiency issues

• **Combined Fragmentation**
  – Natural AND preformed/scored fragmentation
  – Multiple materials (eg: steel and tungsten)
  – Maintain structural integrity where required, use preformed/scored fragmentation elsewhere
  – Require new modeling methodology
Fragmentation Modeling
Modeling Methodology

• **Warhead Mechanics (early time)**
  – Arbitrary Lagrangian/Eulerian High Rate Continuum Modeling: CALE (LLNL) finite difference program
  – Velocity and Mass Distributions

• **Fragmentation Modeling**
  – Hybrid Analytical and Empirical Approach
  – Natural Fragmentation: Mott based model
  – Preformed/Scored Fragmentation: Experimentally based size distribution
Fragmentation Modeling

Natural Fragmentation: CALE

Explosive

Hardened steel shell

Copper shaped charge liner

Steel fragments

Copper jet

$R$

$t=0 \, \mu\text{sec}, \frac{V}{V_0}=1$

$t=8 \, \mu\text{sec}, \frac{V}{V_0}=3$

$t=20 \, \mu\text{sec}, \frac{V}{V_0}=14$

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Natural Fragmentation: CALE

Experimental Data
Fragmentation Modeling

Natural Fragmentation: CALE
Fragmentation Modeling

Natural Fragmentation: Mott

Stress Release Wave
Fracture
Region Under Plastic Expansion
Region Stress Relieved

\[(R_i, z_i)\]
\[\Delta \theta\]
\[r_i\]
\[\theta_j\]
Fragmentation Modeling

Natural Fragmentation: Mott

Fragment Size Distribution:

\[ N_j(m) = N_{0j} e^{-\left(\frac{m}{\mu_j}\right)^{1/2}} \]

\[ \mu_j = \sqrt{\frac{2}{\rho} \left( \frac{p_F}{\gamma} \right)^{3/2} \left( \frac{r_j}{V_j} \right)^3} \]

Total Number of Fragments:

\[ N_{0j} = \frac{m_j}{\mu_j} \]

\( \gamma \) is a statistically based material dependant constant
Fragmentation Modeling

Natural Fragmentation: Mott

γ calibration
γ = 12 final value, V/V₀ = 3 (t = 8 μs)

Experimental Data

CALE-MOTT analyses, t = 20 μs, γ = 30
CALE-MOTT analyses, t = 8 μs, γ = 30
CALE-MOTT analyses, t = 8 μs, γ = 12
CALE-MOTT analyses, t = 8 μs, γ = 5
Fragmentation Modeling

Natural Fragmentation: Mott

\[ \gamma = 12 \text{ final value, } \frac{V}{V_0} = 3 \ (t=8 \mu s) \]
Fragmentation Modeling

Preformed Fragmentation: CALE

Explosive

Steel shell

Copper shaped charge liner

Steel fragments

Copper jet

$\text{t}=0\mu\text{sec}, \text{V/V}_0=1$

$\text{t}=20\mu\text{sec}, \text{V/V}_0=4$

$\text{t}=30\mu\text{sec}, \text{V/V}_0=6.8$

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Preformed Fragmentation: CALE
Fragmentation Modeling

Preformed Fragmentation: Analysis

- Preformed, $2\mu_0 = 3$ grains, $t=10\mu$sec, $V/V_0=3.4$
Fragmentation Modeling

Summary

- New Fragmentation Simulation Capability
- Natural Fragmentation
- Preformed and Scored Fragmentation
- Combined Fragmentation
  - Required new modeling methodology
  - Natural/Scored/Preformed, multiple materials
  - Currently being applied on the ALACV program