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Warhead Mechanics 3 days 3 instructors

OVERALL OBJECTIVES:

In the context of detonation-metal interactions, this course will describe the operating mechanics of the main types of military warheads, including fragmentation warheads, shaped charges, explosively formed projectiles (EFPs), and multimode and tandem warheads. The mechanics of hydrodynamic penetration, the kill mechanism for many of these warheads, will be presented. Experimental methods, including interferometry, ultrahigh-speed photography and radiography, that are useful in studies of detonation behavior, warhead development and performance evaluation will be discussed in connection with descriptions of some results obtained with them. Effectiveness of these warheads can often be enhanced by the location and timing of initiation of detonation or by initiation at multiple points. This initiation technology will also be discussed, with emphasis on slapper detonator systems that enable selective firing and electronic safing and arming (ESAFs). This course is intended to provide a useful overview and specific design guidance suitable for staff involved in warhead design, development and testing, fuze designers and systems analysts. The topics of reactive materials, air blast and heterogeneous blast will not be included in this course. *Prerequisite:* Participants will need to have taken "Fundamentals of Explosives" or have equivalent experience with shocks and detonation in order to benefit fully from this graduate level course.

LEARNING OBJECTIVES:

At course completion, each student should be able to understand the following fundamental points concerning the principal types of military warheads:

Fragmentation warheads:

1) Gurney equations to estimate fragment velocities and direction
2) Fragment formation and size by Mott model
3) Fragment penetration - Thor penetration equations, Mascianica's data fits, effect of air drag on fragment range, roles of Fraghaz and CONWEP codes.
4) Arena tests
5) Fundamentals of Fragmentation *(diagnostic techniques indicated in parentheses)*
   a) Stress state effects: bacon strips and corn flakes
   b) Micromechanics of fragmentation: rupture; shear banding and intermediate effects; brittle response in warhead metals

c) Shear localization: defect structures and nucleation; propagation, coalescence, and separation
d) Fragmentation under homogeneous spherical expansion: filled hemi system definition and characterization ("Low energy" radiography, techniques and tools; Radiographic process and analysis)
e) Measures of strain to failure and localization onset (surface perturbation) (Speckle interferometry)
f) Statistical size distributions: Poisson statistics; numerical studies
g) Physics-based size distributions: Mott, Grady-Kipp

Explosive/Metal Interactions:

1) Shock and detonation interaction with interfaces:
   a) 1D waves; sweeping waves; 1D spall; ring spall - warhead front, blast shields (Laser velocity interferometry, pins)
   b) Shock dynamics, curvature effects, Detonation Shock Dynamics – DSD (Streak camera techniques)
   c) Reaction zone effects, von Neumann spike interactions
2) Multidimensional shock and detonation interactions
   a) Mach stems, regular reflection, metal cutting with HE drive ("Penetrating" x-radiography)
   b) Wave shapers, multipoint initiation
3) Inertial effects
   a) Tampers and shape spreading; tabs and stabilization fin formation
   b) HE products interactions - penetration of high pressure gas; transverse interactions of gas with jets; interface gaps; unstable motions (Rayleigh-Taylor, Helmholtz, etc.) (Structured light photography, Proton radiography)

Explosively formed projectiles (EFPs):

Mechanics of liner inversion to form an aerostable projectile

Shaped charges:

Mechanics of shaped-charge jet formation and penetration, including:

1) Jet formation in conical shaped charges, to include PER theory.
2) Criteria for jet formation.
3) Differences between conical shaped charges and hemispherical shaped charges.
4) The concept of virtual origin and jet breakup time
5) Hydrodynamic jet penetration theory
6) Penetration-standoff curves and the Fireman-Pugh technique
   1. Effects of target strength and compressibility on penetration
   2. Hole diameter effects
   3. Jet disruption: effect of transverse velocity and factors limiting penetration

4. Hole closure and "bulking"

Brief discussion of armors for the defeat of shaped charges.

Roles of initiation to enhance warhead performance:

Slapper detonators and multipoint slapper arrays
Shock initiation of the explosive in a slapper detonator and detonation spreading
Dynamic diagnostics for observation of slapper performance
Electronic safing, arming and firing (ESAF) systems that satisfy Mil-Std 1316
Firing circuits for slapper systems
Selective initiation, timing of firing multiple arrays

Multimode and tandem warheads

IMMEDIATE BENEFITS:

Each student who completes this course will gain a rounded understanding of the performance capabilities and limitations of the principal types of warheads as well as an understanding of the mechanics of driving metal with detonating explosives and instrumentation methods by which measurements can be made. He or she will be placed in a position to apply the best design methods and experimental evaluation techniques for the benefit of a project. This extends to fragmentation, shaped-charge, EFP and multimode warheads, and the initiation of them.

INSTRUCTORS:

The instructors for this course will be Dr. Robert Frey, now of DSI but formerly an employee of the Army Research Laboratory, Dr. Larry Hull and Dr. Keith Thomas of Los Alamos National Laboratory (LANL), and Dr. James Kennedy of HERE, LLC. Dr. Frey has over 40 years of experience in R&D involving explosives and armor. Dr. Hull has worked at LANL for over 25 years in detonation physics, detonation drive of metals for warhead applications, and wave-propagation code simulation of these behaviors. Dr. Thomas has over 20 years of experience in experimental detonation physics and the development of dynamic diagnostic techniques and detonators and for the Air Force Research Laboratory and LANL. He has worked at numerous DOD, DOE and commercial explosive firing sites in the US and the UK. Dr. Kennedy has over 40 years of experience in explosives work including large-scale field work, analysis of explosive performance, gas-gun experiments, and development of detonators and small-scale explosives tests.