THE UNKNOWN DETONATION TRANSITION (XDT) MECHANISMS ASSOCIATED WITH DAMAGED ROCKET PROPELLANT IMPACTING A SURFACE: UNDERSTANDING AND APPLICATIONS TO IM

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U.S. Army Aviation and Missile Research, Development, and Engineering Center

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• Motors need to pass insensitive munition fragment impact requirements
  – Better understanding of motor reaction needed
• Motors containing 1.1 propellant can detonate via
  – Shock to Detonation Transition (SDT)
  – Unknown Detonation Transition (XDT)
  • More prevalent problem than previously thought
• MSP-1 propellant
  – ABVR web thickness – 1.25 or 2.50 in
  – Cylindrical web thickness – 1.09 or 2.34 in
• Pressure gauges set at a 45° offset
• High speed cameras used to optically record event
• Change from XDT to brief combustion caused by debris cloud porosity
  – Visual break up of cloud correlates to XDT limit

Data from Finnegan et al., Int. J. Impact Eng., 1993.
Upper XDT Limit

XDT – 3976 ft/s

193.5 µs

206.4 µs

197.8 µs

210.7 µs

202.1 µs

215.0 µs

Brief Combustion – 2756 ft/s

193.5 µs

206.4 µs

279.5 µs

283.8 µs

292.4 µs

301.0 µs

309.6 µs

318.2 µs
• The variation with fragment velocity appears to correlate with the amount of material in debris cloud
  – Material in debris cloud $\propto$ kinetic energy of fragment, thickness of propellant, and presented area of fragment
  – More material means longer length required to obtain porosity necessary to mitigate XDT
• Impact of debris cloud appears to cause localized SDT on leading edge of propellant debris cloud
  – Reaction propagates back through debris cloud at the velocity typical of a detonation through highly porous material
• Velocity increases as porosity decreases

XDT – 3976 ft/s
- Decreasing cloud porosity decreases sensitivity to SDT
- Increasing cloud temperature increases sensitivity to SDT
Conclusions

• XDT is likely a prominent detonation mechanism in real rocket motors and needs to be mitigated
• XDT can be controlled by influencing properties of the propellant debris cloud
  – Porosity
  – Temperature
• Mitigation strategies
  – Eliminate cavity
    • Completely solid fuel grain
    • Insert material
  – Design cavity to negate hazards associated with debris cloud
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