Reducing HE Response Severity by Varying the Confinement around an Explosive Charge to Improve IM Signature

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Introduction

- IM Systems: Reduced possibility of unintended Violent Reaction (VR) throughout lifecycle
- Munition will not be in Packaging all of lifecycle (e.g. manufacture, testing/practice firing and disposal)
- During these unpackaged stages, munition is most likely to suffer low speed impact (result of drops or transportation accidents).
- Is it possible to reduce possibility of VR during low speed impacts by altering confinement (such as case thickness) to improve safety signature?
- For most munitions it may not be appropriate to pursue this …… but for some high cost / consequence munitions it may be desirable

What is being Presented?

- Questions:-
  - Is it possible to reduce possibility of Violent Reaction during low speed impacts by altering confinement ?
  - Can margin between munition and confinement that produces VR be quantified ?

- Use simple Ignition → Burn → VR type concept experiments rather than system geometry (expensive)
  - Alter:-
    - Confinement (thickness and material)
    - Ignition mechanisms (severity of initial reaction)

- Lessons learnt – good and bad points

Hypothetical Accident Scenario

- Impact damages Energetic Material (EM)
  - Higher porosity enables burn front to accelerate faster (to a limit)

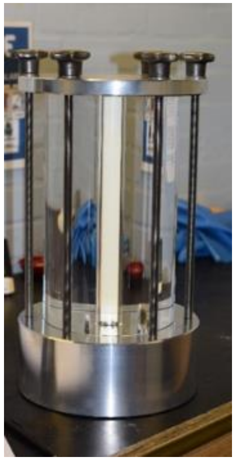
- Localised ignition in high porosity EM. localised ignition
  – Point heat source (e.g. hot metal fragment @ 700°C – relatively gentle ignition)
  – Spigot intrusion with pinch of HE against hard surface (spigot pierces system – more severe ignition as temperatures of >> 700°C can be generated)

Concept Test Design

- Based on Deflagration-to-Detonation Transition (DDT) lab tests
- EM details:
  - high (91% by wt.) HMX content. Other 9% wt was plasticiser binder.
  - used in powder form to obtain high porosity (approx. 1 g/cc c.f. 1.9 g/cc for consolidated) representing severe mechanical damage (and for ease of assembly).
  - test sample 25 mm dia., 300 mm long column, sieved to two different particle size ranges (< 1400µm and 1676 to 2500µm) ….. stochastic results did not indicate any significant difference in behaviour
- Ignition – thermal and impact (localised in EM)
- Initial tests used high confinement (steel) test vessel but replaced in latter tests by transparent media to enable viewing of burn front progression

Glow-Plug Ignition **Slow build-up in violence/pressure (relatively)**

- Basic design



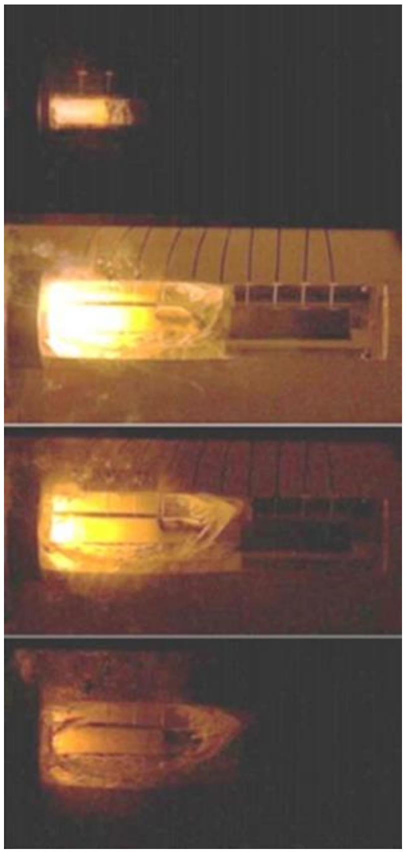
- Three variants in concept vessel (ideally only one):-
    - Steel confinement (5 to 20 mm wall thickness)
    - PMMA confinement (25 & 75 mm wall thickness)
    - Steel with 300 x 14 x 14 mm quartz window rod (quartz weak link)
- PMMA and quartz window used to enable observation of burn in EM

Glow-Plug Ignition Results

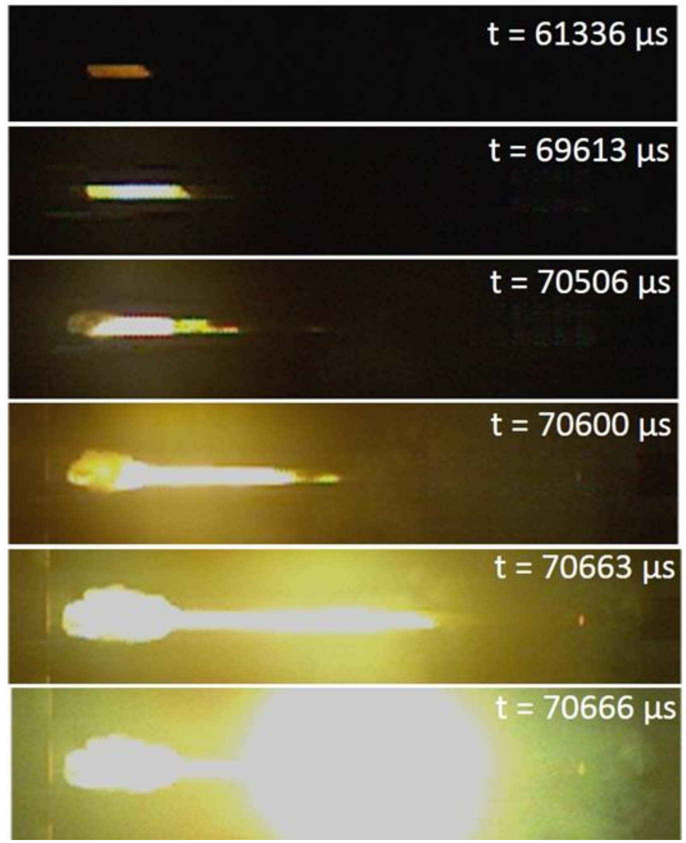
Confinement Material	Wall Thickness mm	Quasi Static Confinement Strength MPa	EM Response
Steel	5 to 20	85 to 180	VR
PMMA	25 and 75	22 and 28	Fail / pressure burst
Steel with quartz window	14 mm quartz	35	VR

- Confinement strength of PMMA and Quartz window test vessels measured using pressure rates of ~ 6 $MPa.s^{-1}$. Steel test vessels strength calculated using (simple) Barlow's formula.
- Acknowledged that this is slow pressurisation rate compared to EM experiments – more on this later

Examples of Glow-plug ignited Results

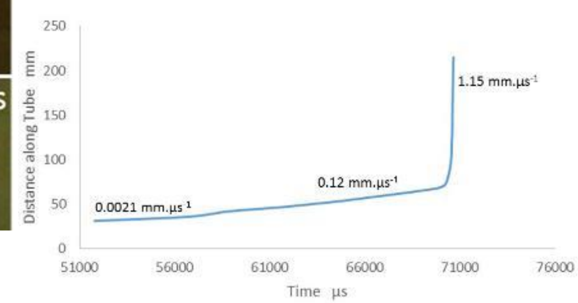


PMMA 25 mm wall thickness
Reaction self extinguishing

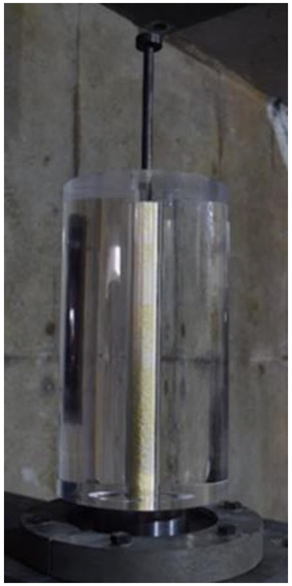


Quartz window vessel
Violent Reaction

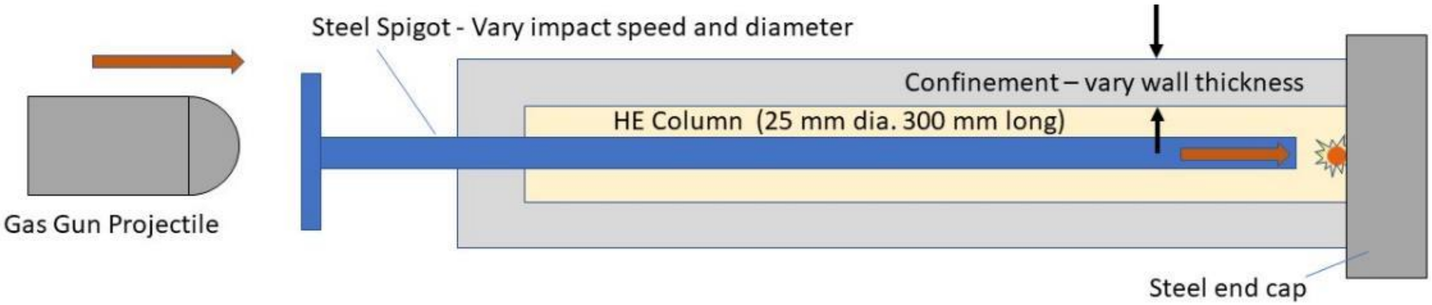
Post test
Quartz window
Vessel remnant



Spigot Impact Ignition **Stronger ignition source – higher temperature**



- Basic design



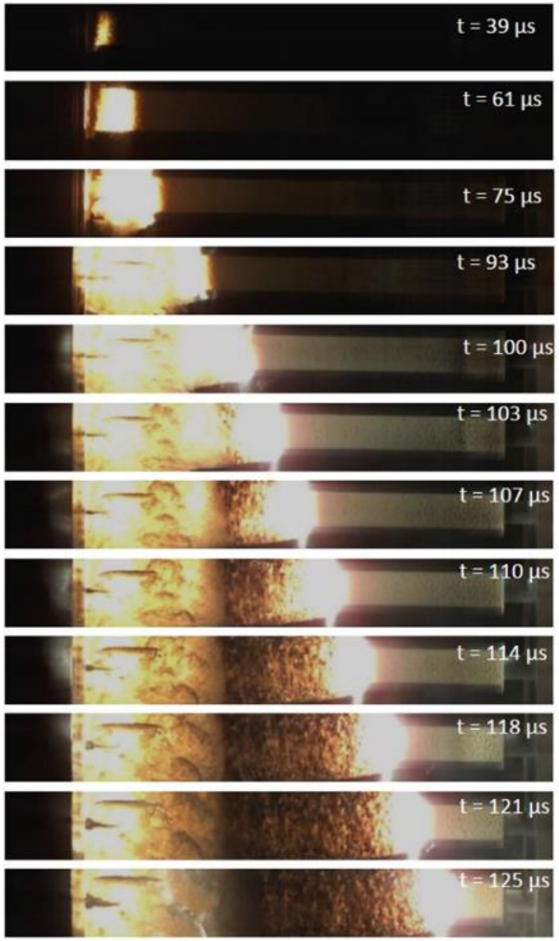
- Two variants:-
  - Steel confinement (25 mm wall thickness)
  - PMMA confinement (25 & 75 mm wall thickness)

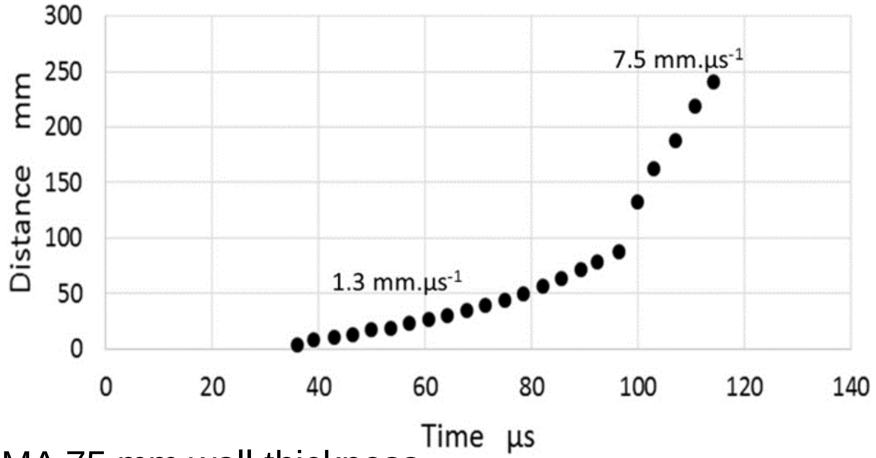
- Spigot diameter and Impact speed examined

Spigot Impact Ignition Results

Confinement Material	Wall thickness mm	Quasi Static Confinement Strength MPa	Spigot Diameter mm	Spigot Speed at pinch $m.s^{-1}$	EM Response
Steel	25	200	6 9 12 15 20	~ 90 ~ 90 ~ 90 ~ 90 ~ 90	Fail Fail VR VR VR
PMMA	25	22	12 15	70 70	Fail /Pressure burst Fail /Pressure burst
PMMA	75	28	2 4 6 11 11	60 60 60 < 55 >55	Fail Fail Pressure burst Fail/Pressure burst VR

Example of Spigot Impact Ignition Results





PMMA 75 mm wall thickness
Reaction building to detonation
after approx. one-third travel

Steel vessel
post-test remnants

Review of Test Results

- Experiments demonstrated that (in certain cases) EM explosiveness can be controlled by altering the confinement
- Test methods need refining e.g.
  - long spigot can flex – non symmetric impact producing different ignition patterns.
  - Avoid use of certain materials – PMMA and Quartz micro-structural flaws considerably lowers failure strength from theoretical values - tests results suggest by a factor of about 2)
- Pressure testing of vessels is quasi-static – different failure strength to dynamic high strain rate. Further complicated if different confinement materials (c.f. munition) used as likely to have different Dynamic Increase Factor (DIF) for failure strength

Summary

- In certain circumstances, reaction growth can be controlled by altering the confinement
- Viable method for controlling response of munitions in accidents? – depends on many factors – probably applicable for limited number of munition systems
- Cost-Benefit ? – limited period system is vulnerable
  - use same confinement material in tests as case material around EM in munition to avoid DIF in order to provide (less complicated) quantitative confinement strength comparisons
  - Consider using weak seams or vent ports??