IM Rocket Motor Design and Assessment

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A presentation to: IMEMTS 2015

Rome

QinetiQ/15/01126

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UNIVERSITY OF CAMBRIDGE

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UK needs to design and manufacture IM rocket motors and assess foreign rocket motors for in-service use under a wide range of conditions. Missile systems used in current operations theatres are vulnerable to bullet and fragment impact.

Fragment impact generates a propellant debris cloud that surrounds the projectile as it crosses the bore of the rocket motor and on impact can lead to an XDT response.

Requirements

Research Programme:

Demonstrate a predictive modelling capability for XDT in rocket motors.

Define and demonstrate materials characterisation programme required for rocket motors

Develop and demonstrate small scale testing required to characterise propensity of a rocket motor propellant to produce an XDT response.

Produce a dataset showing XDT trends as a function of motor design and propellant characteristics.

Technical Approach

Simulation/experiment of small scale representation of bore/web.

Identify known XDT phenomenology.

Develop small scale tests that exhibit XDT.

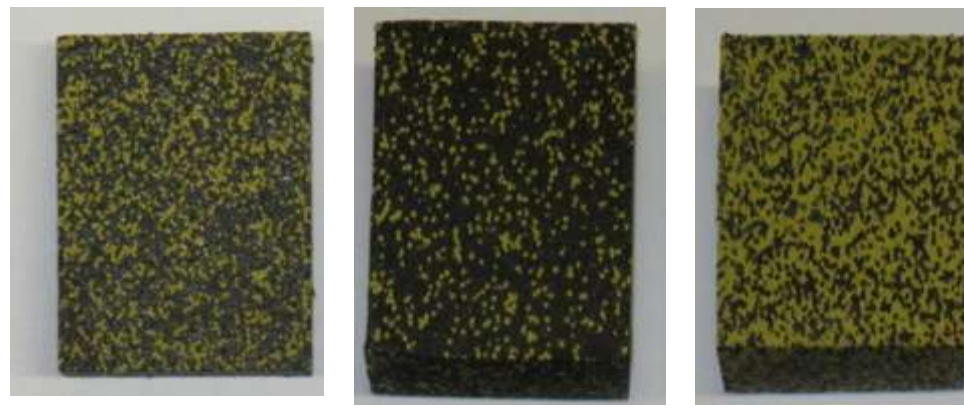
Build integrated thermo-mechanical-burning model for propellants.

Validate model.

Propellant Materials

Powder blends with varying amounts of yellow (y) and black (b) pellets, where the yellow pellets contain the nitramine:

- Propellant A (2y:3b)
- Propellant B (0y:5b i.e. 0% nitramine)
- Propellant D (1y:4b)
- Propellant E (3y:2b)



A D E

Small Scale Tests

Fragmentation

- Understand how the material fragments

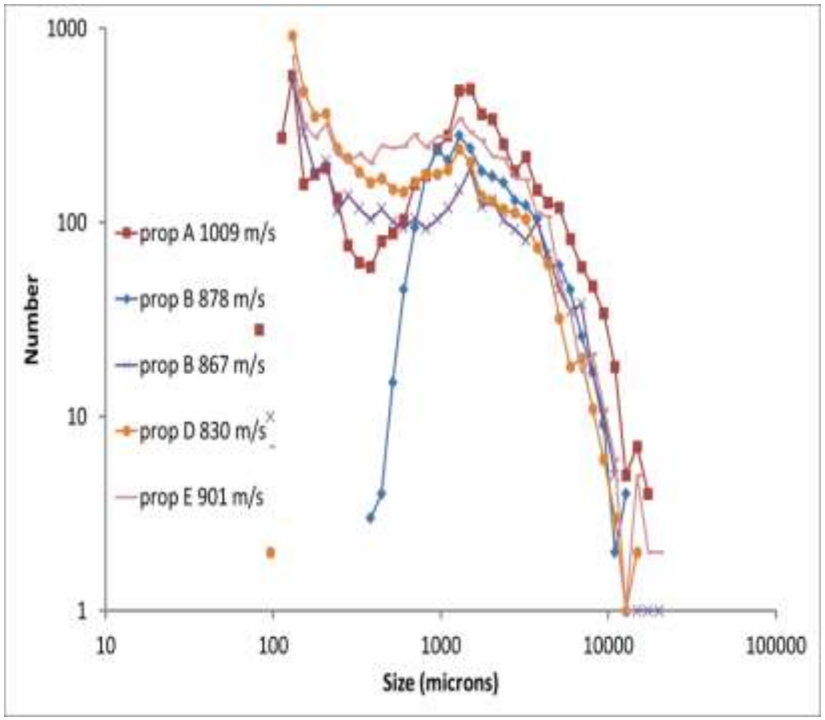
Impact event characterisation

- Burning
- XDT
- SDT

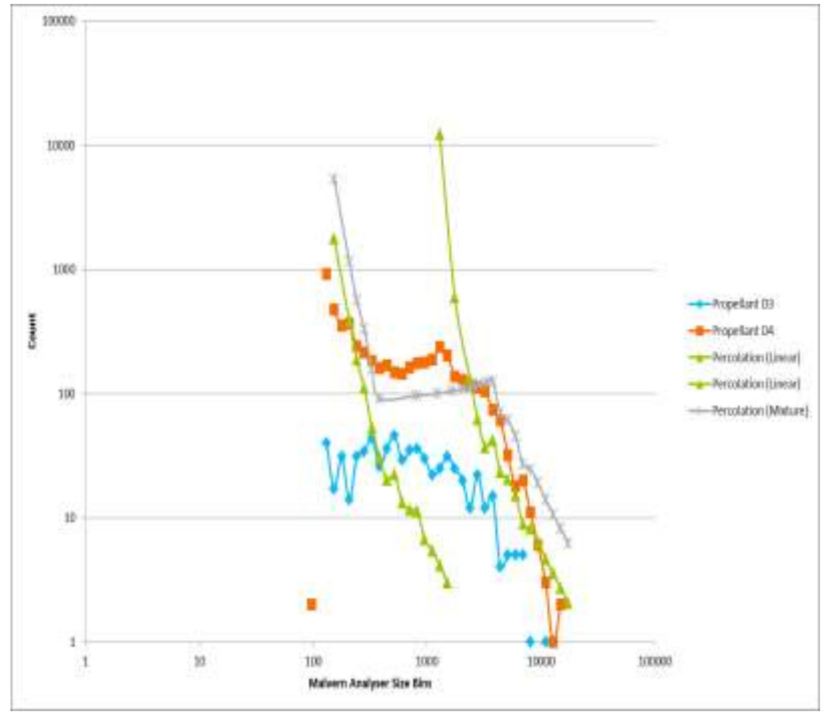
Fragmentation

Fragmentation

Experimental Results



Percolation Model: Propellant D



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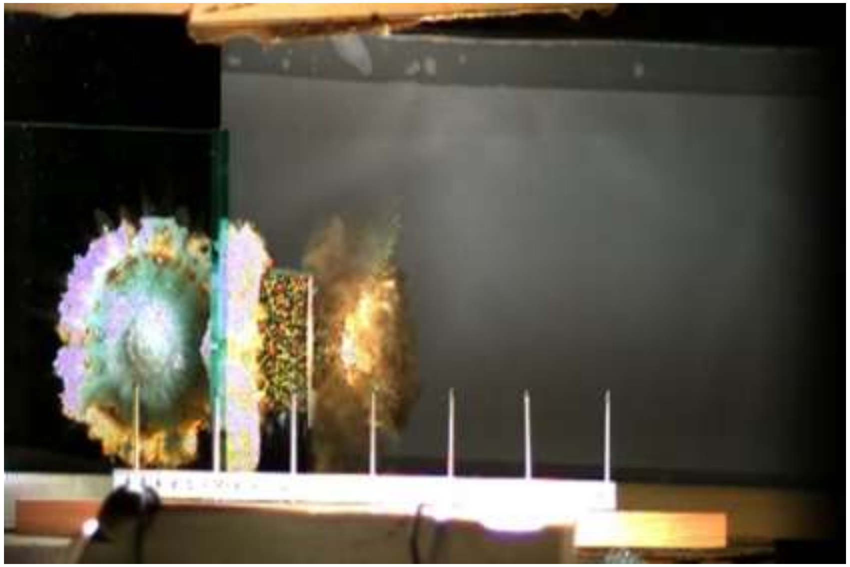
Impact

Propellant A (2y:3b). Round 49 V= 1430m.s^{-1}

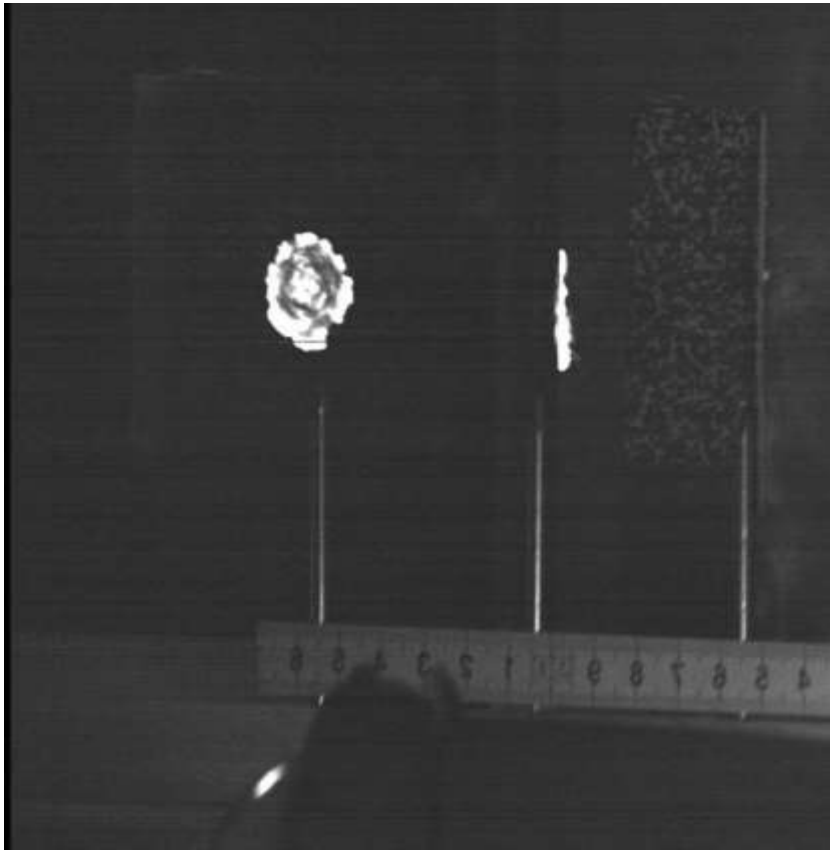


Impact

Propellant A (2y:3b). Round 49 V= 1430$m.s^{-1}$

Karana Camera

Impact



Karana Camera

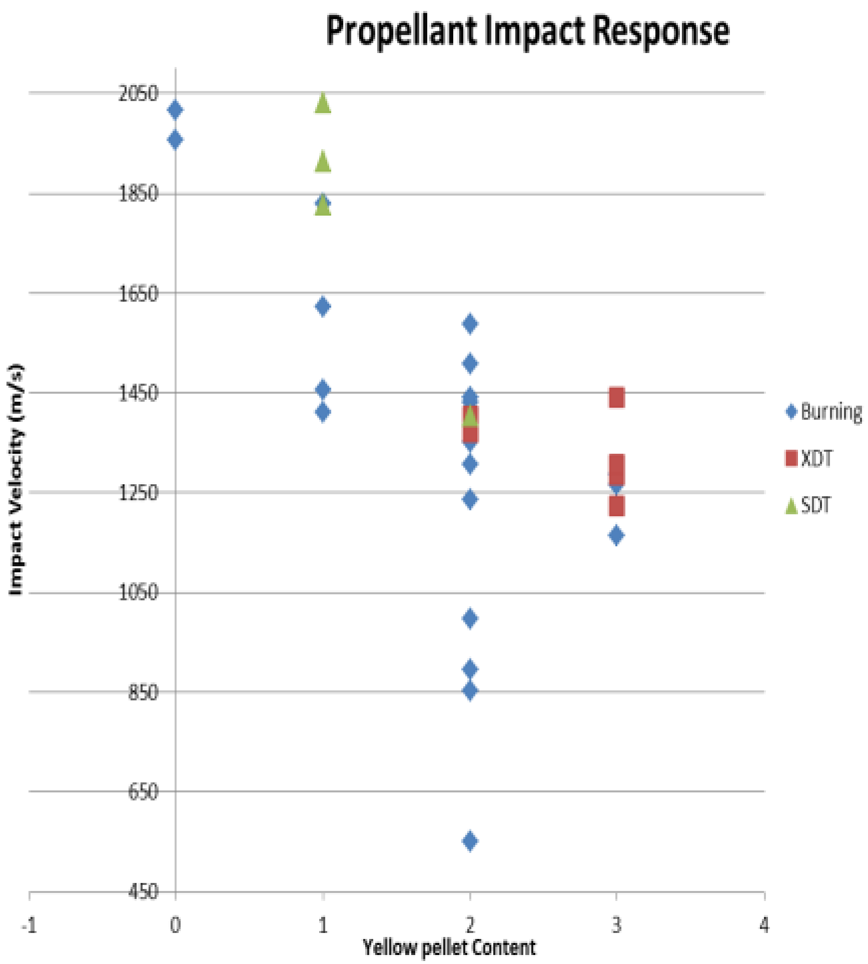
Impact

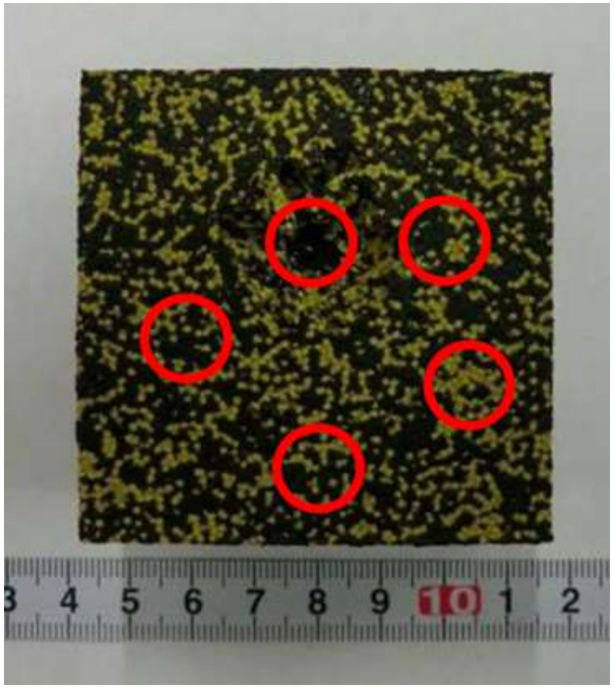
XDT: Propellant A onto B 1441m.s^{-1}

Impact

Propellant E (3y:2b) onto glass 1373m.s^{-1}

Response Thresholds





XDT Characterisation

Material Model

Initial model based on available data and assumptions about the distribution of the NG in the nitrocellulose.

Available data have demonstrated the models ability to predict density, modulus, loss tangent well and other properties (Hugoniot).

There are three levels of material complexity that can be examined for validation data: the components, the pellets and the moulded propellant.

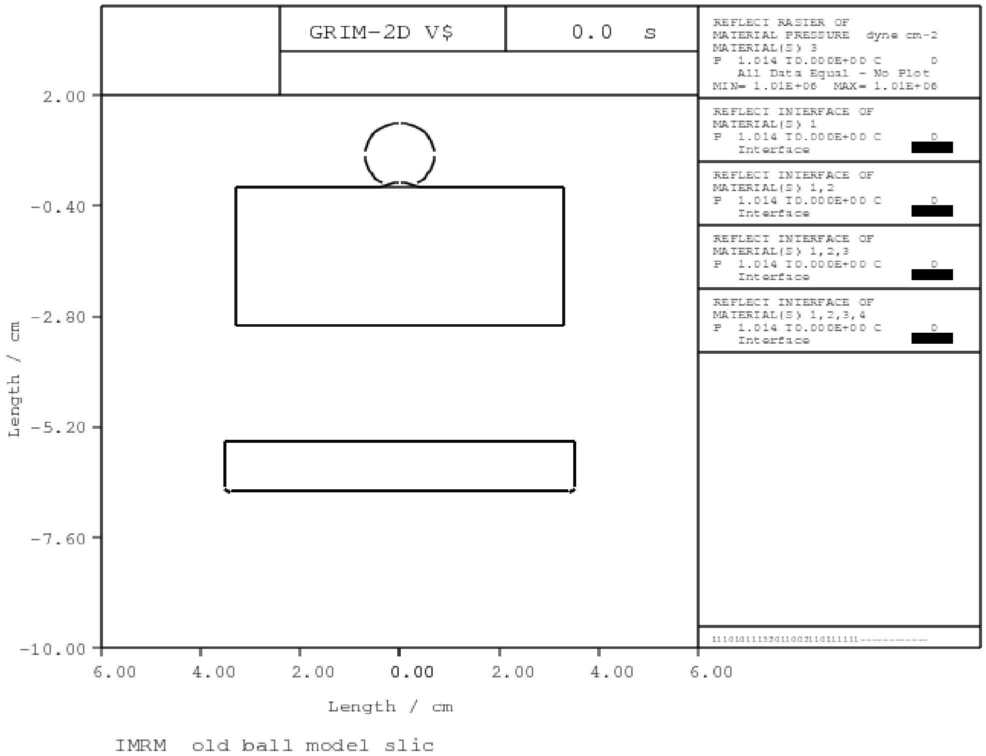
Modelling

CHARM is a semi-empirical ignition and growth model that employs a physically based description of hot spot collapse processes to describe the SDT response in an energetic material. It includes a 3-step Arrhenius scheme to represent the chemistry of the reaction.

The Porter-Gould material model employs materials science to predict the Equation of State and constitutive response of a material. In the case of composite energetic materials this includes damage and fracture.

Modelling

Propellant A: 1370m.s^{-1}

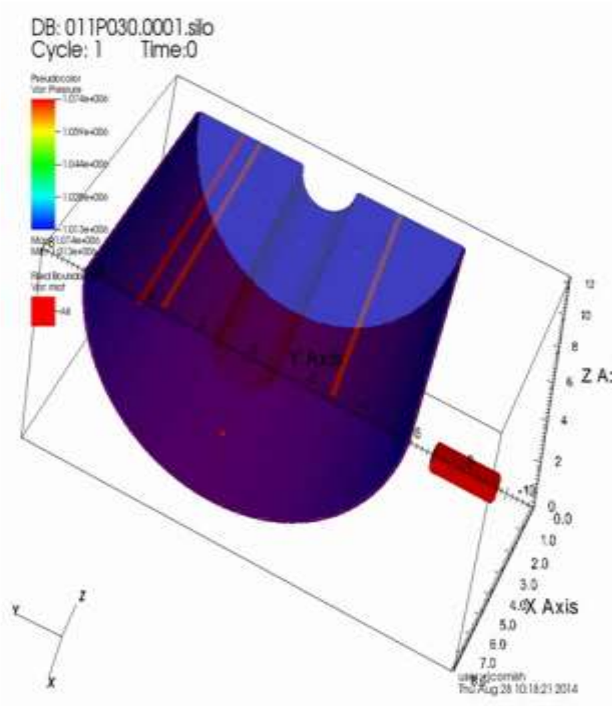


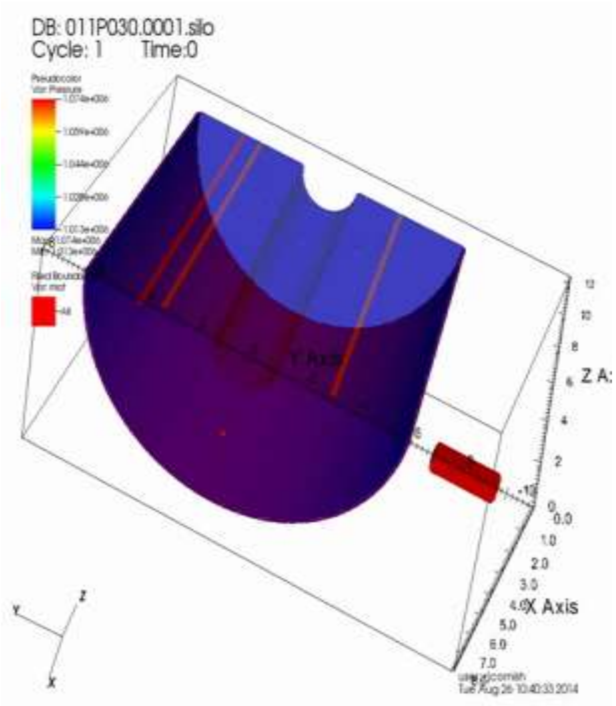
System Modelling

Full scale rocket motor

- Fragment attack experiments conducted in 1995
  - Burning response at impact velocity of 1451m.s^{-1}
  - XDT at impact velocity of 1897m.s^{-1}

System Modelling





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Conclusions

The small scale experimental programme has been successful and provided invaluable data.

Karana camera data world first providing fundamental understanding of the ignition and growth process

Material model development centred on link between damage and burn rate.

Material characterisation work at Cambridge has made excellent progress and supported material model development.

The development of the CHARM I&G model has represented a significant challenge.

Baseline system level design capability.

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