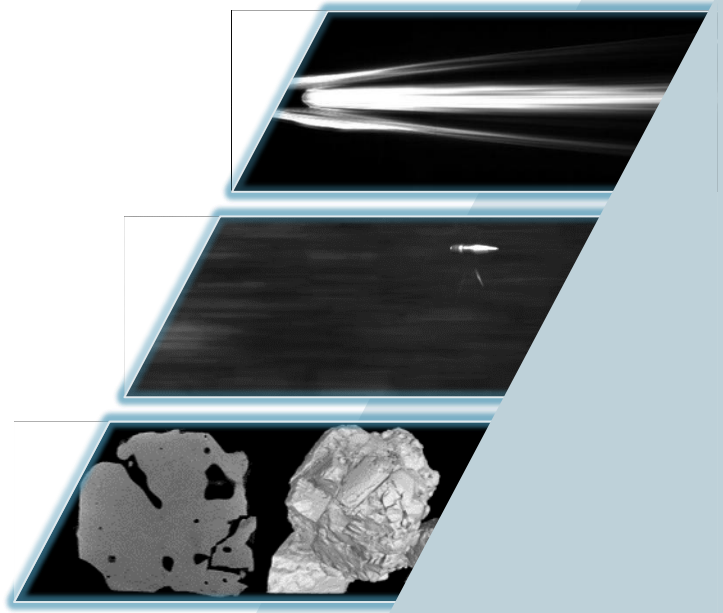

AGEING EFFECT ON THE SHOCK SENSITIVITY OF EXPLOSIVE FORMULATIONS

14/10/2025

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Shock Physics & Detonics Group

A joint initiative of:

AGENCE INNOVATION DÉFENSE
MINISTÈRE DES ARMÉES
Liberté Égalité Fraternité
Bundesministerium der Verteidigung

EDA project IMA: European cooperation on Insensitive Munitions and Ageing (2009 – 2013)

Motivation & Goals

- safety and vulnerability are of major concern for ammunitions
- influence of ageing on energetic materials
- different types of energetic materials (propellants, explosives, gun powder…)

Conclusions

- ageing influences the mechanical properties (hardening) of the energetic materials
- no severe impact on vulnerability

Next Steps?

- investigate the damage mechanisms
- impact of mechanical loads

➢ TVESIM: Thermal & Vibrational loading Effects on Structural Integrity of energetic Materials

- ➢ cooperation between France & Germany
- ➢ labs: CRB-AGS – DGA-TT – ICT Fraunhofer – WTD-91 – ISL
- ➢ started in September 2021

Overview

Investigate the Impact of Ageing on Energetic Materials

- mechanical (vibrational) loading in addition to thermal ageing
- structural grain integrity
  - mechanical properties
  - stability of binder-filler system
  - thermal stability
  - shock sensitivity
- two materials
  - Composite Rocket Propellant (CRP)
    - 82% ammonium perchlorate
    - 4% aluminum
    - 14% binder
  - Plastic Bonded High Explosive (PBX)
    - 81% RDX
    - 4% aluminum
    - 15% HTPB based binder

Overview

Contributions

	CRP	PBX
manufacturing	CRB-AGS	ICT
thermal loading	CRB-AGS	ICT
vibrational loading	DGA-TT	WTD-91
characterization	CRB-AGS, DGA-TT, ICT	CRB-AGS, DGA-TT, ICT, ISL

Characterization techniques

- specific heat capacity, thermal diffusivity, thermal conductivity
- tensile tests
- crystal structure, microstructure
- sensitivity
- ...

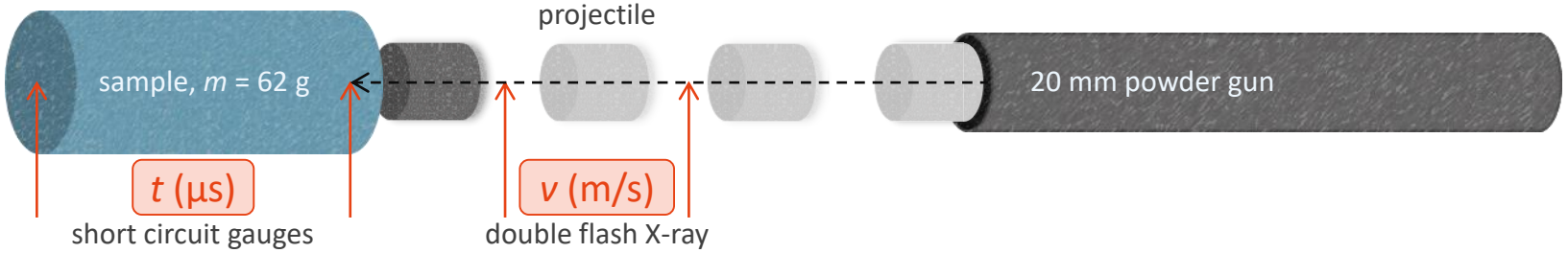
Ageing Conditions for PBX			
20°C		60°C	
thermal	vibrational	thermal	vibrational
		30 d	
		60 d	
		90 d	
		120 d	
		150 d	
180 d	–	180 d	–
	6 h @ +20°C		6 h @ -20°C
			6 h @ +20°C
			6 h @ +60°C
		270 d	
360 d		360 d	
720 d			
1080 d			

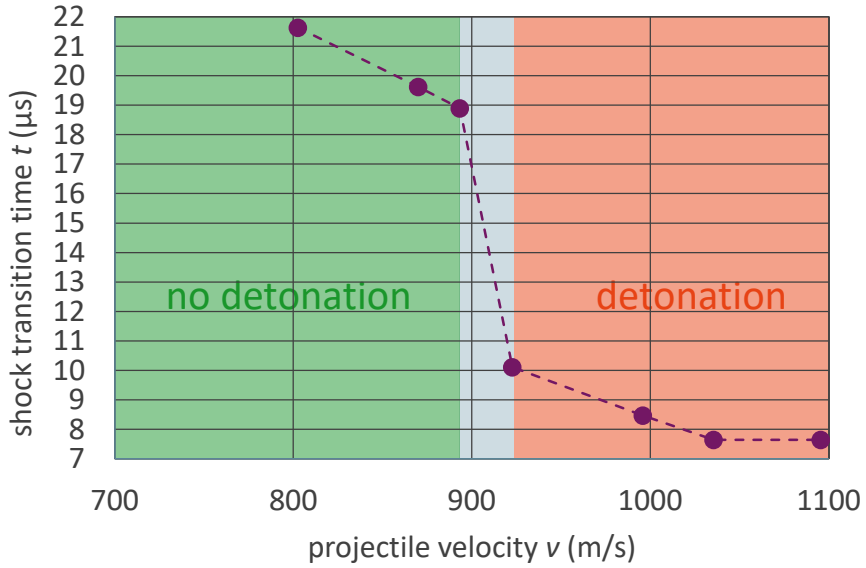
Characterization at ISL

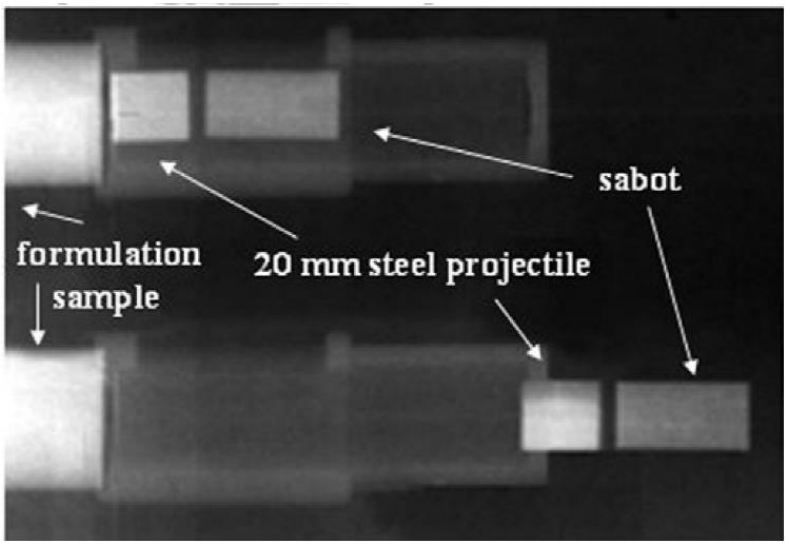
shock sensitivity analyses via:

- Projectile Impact Test
- Small Scale Gap Test

Shock Sensitivity Analysis – Projectile Impact Test



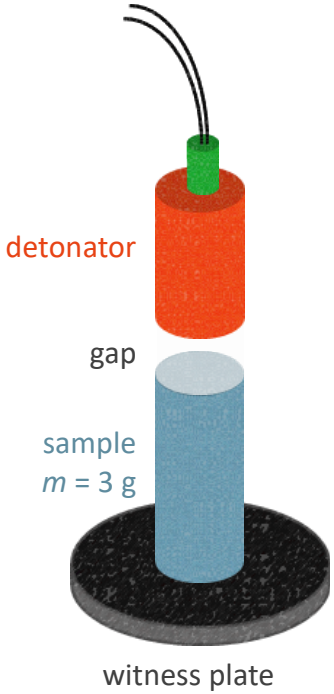


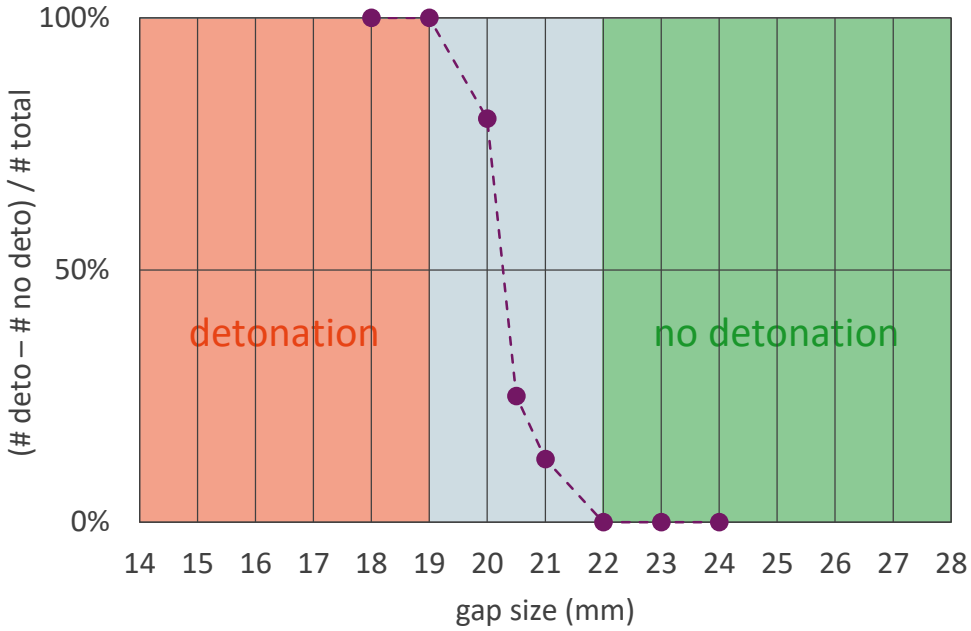


- shock transition time *t*
- projectile velocity *v*

Borne *et al.*, *Propellants Explos. Pyrotech.* **33**, 37 (2008)

Shock Sensitivity Analysis – Small Scale Gap Test



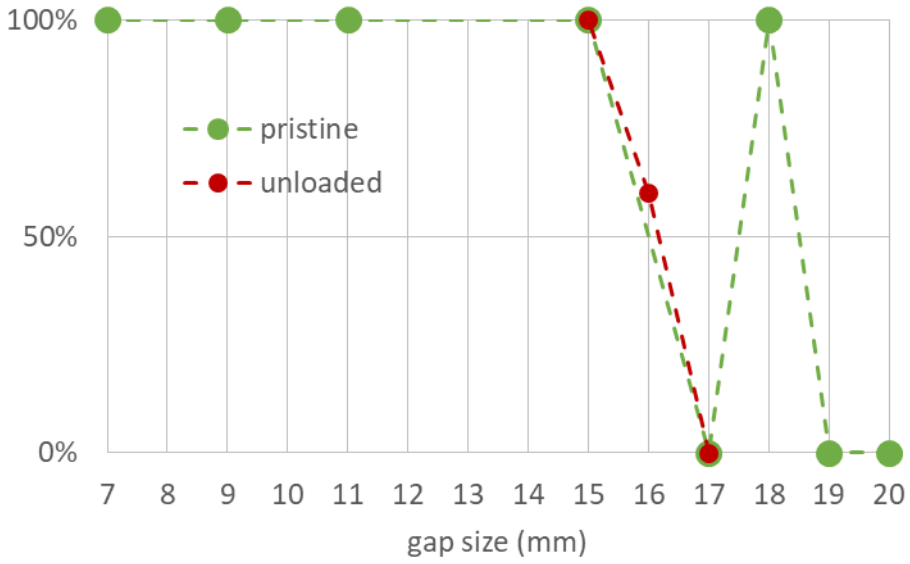


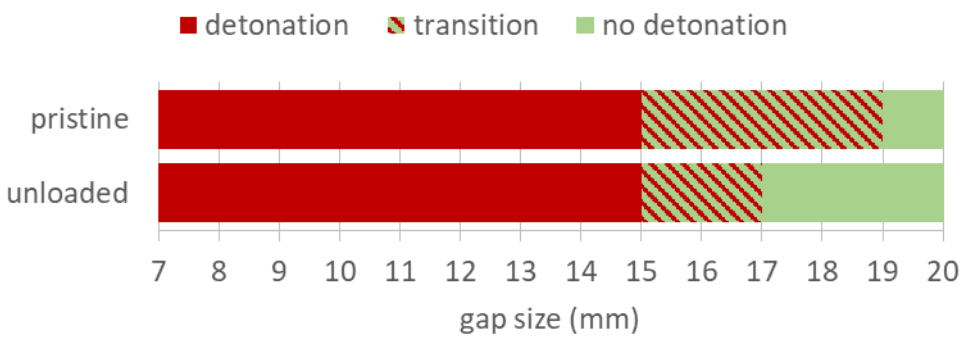
sample	PIT	SSGT
diameter	20 mm	8 mm
mass / trial	62 g	3 g
mass / series*	496 g	24 g

*series: 6 – 8 trials determine threshold value
EM / wax = 70 / 30

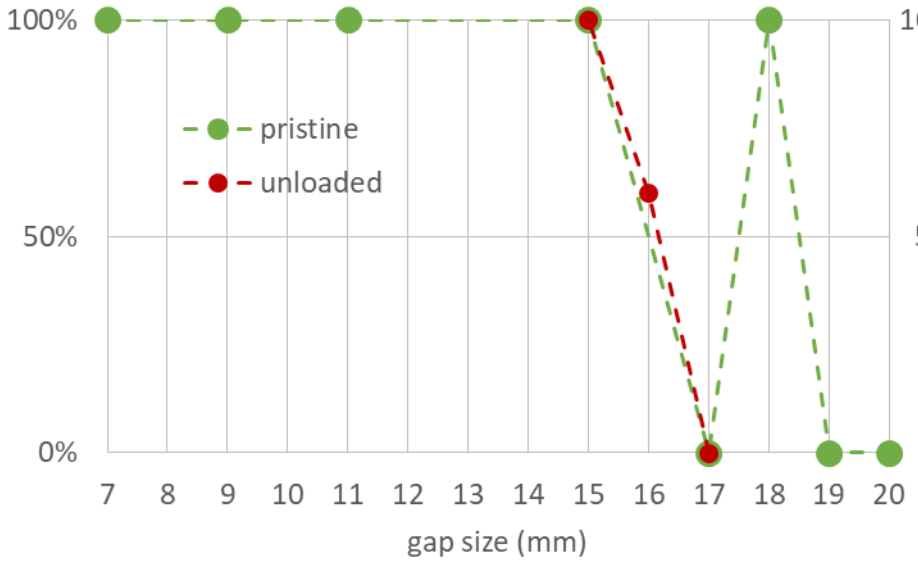
- faster
- reduced cost
- improved safety

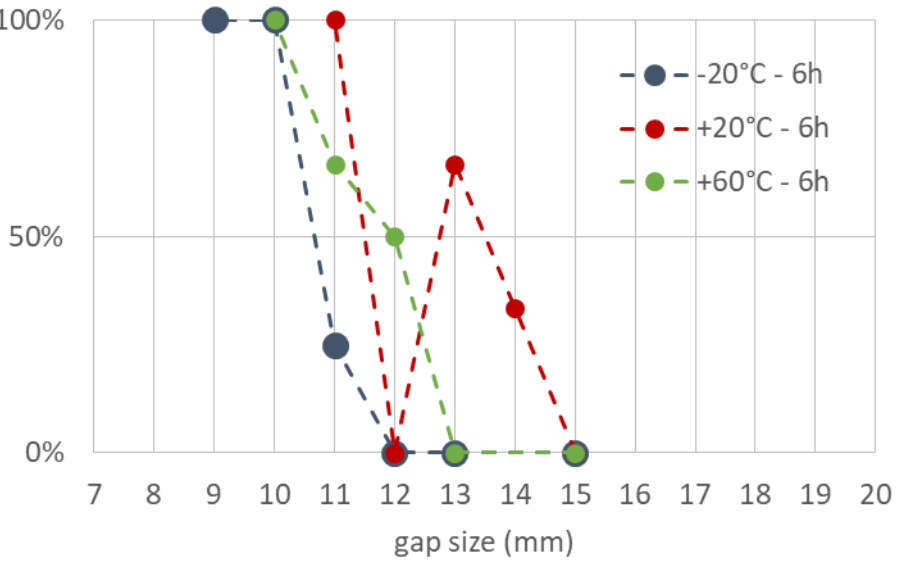
Shock Sensitivity Analysis – Small Scale Gap Test

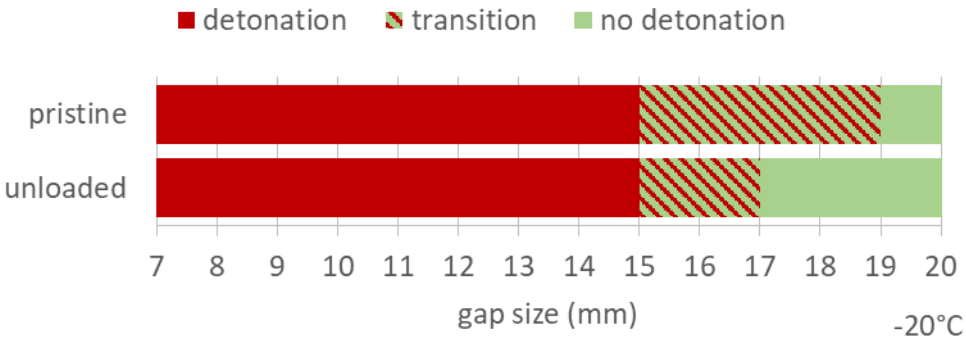


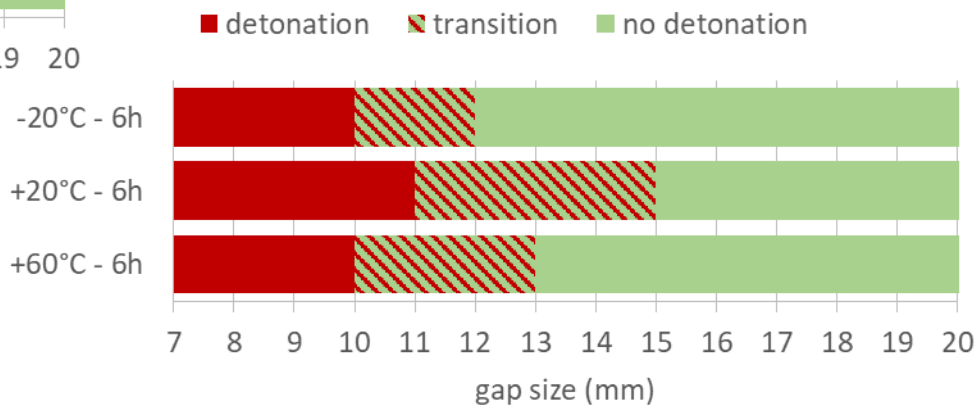


Shock Sensitivity Analysis – Small Scale Gap Test









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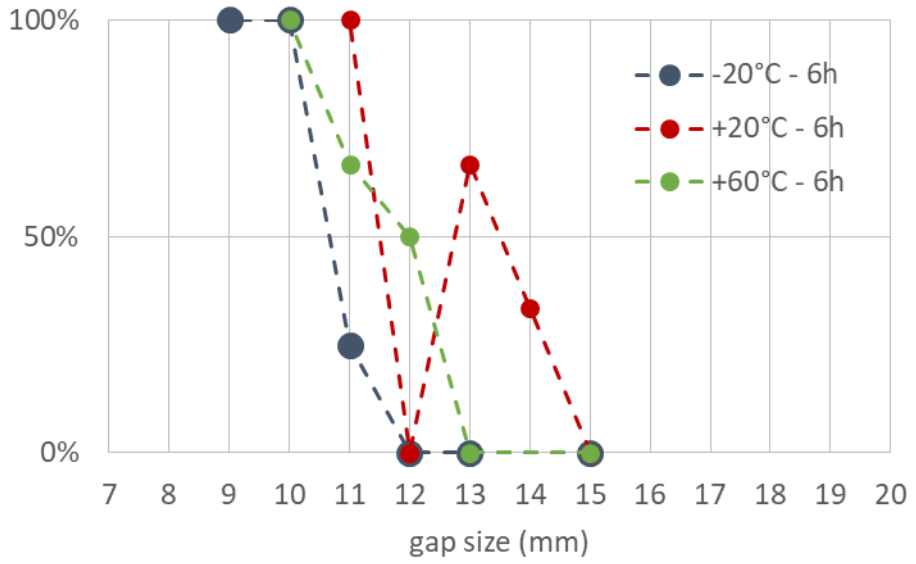
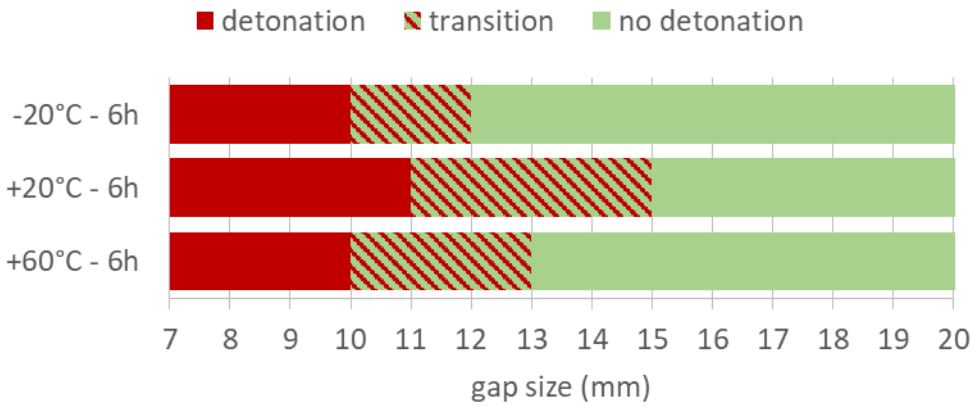
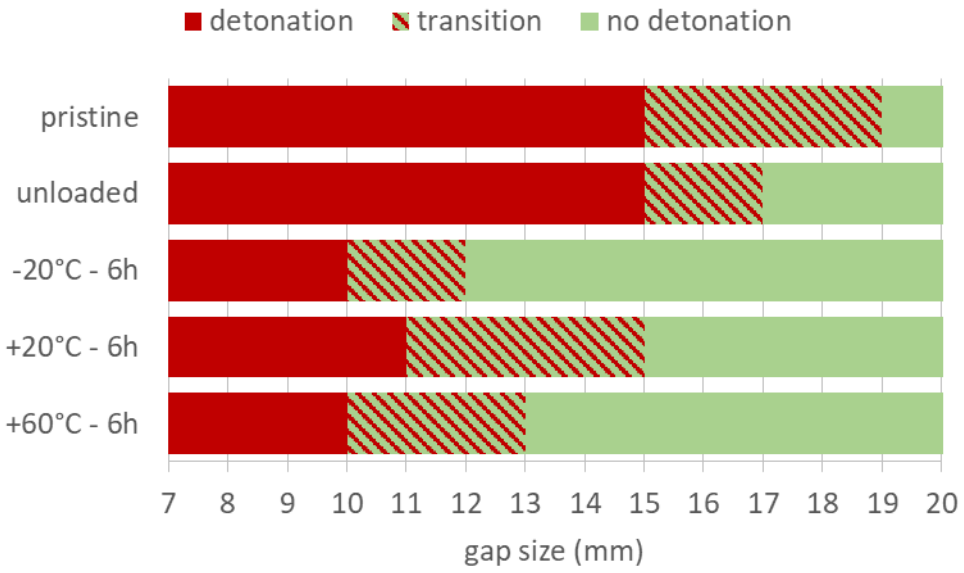


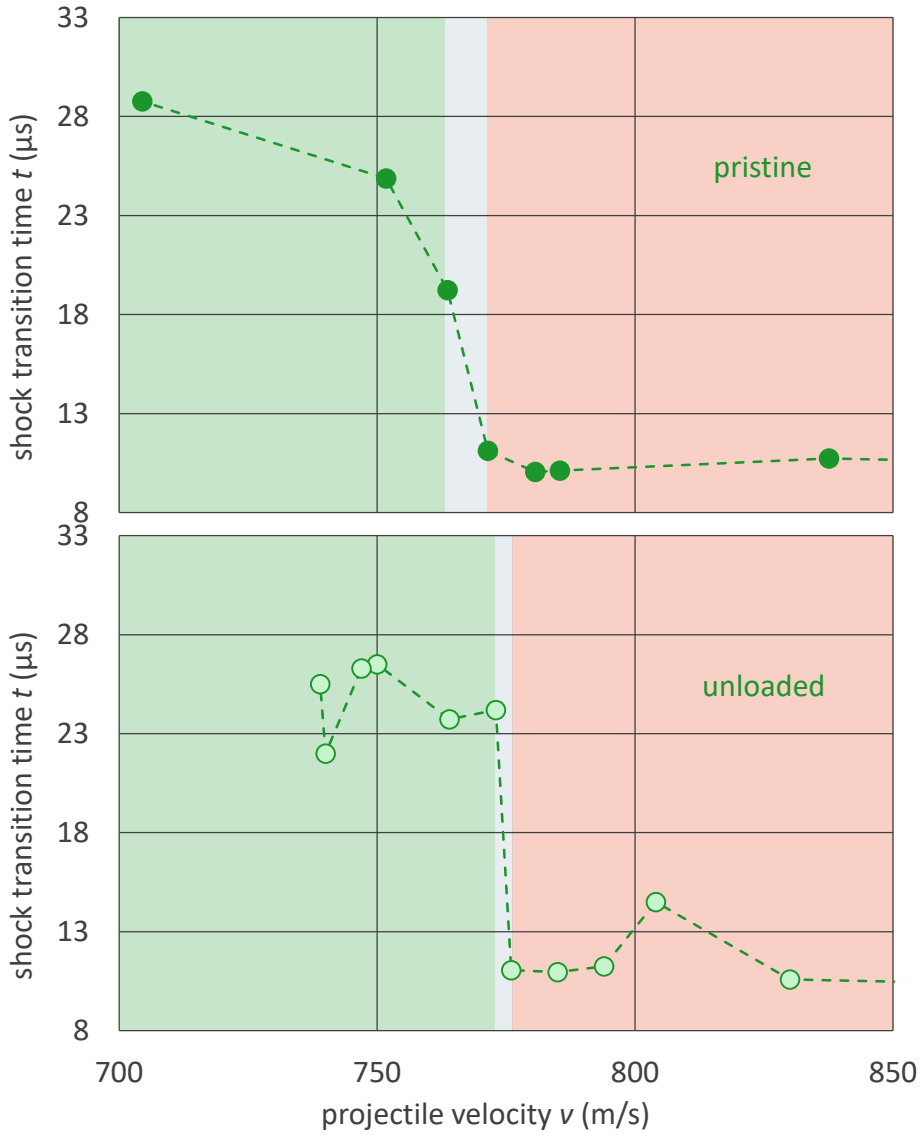


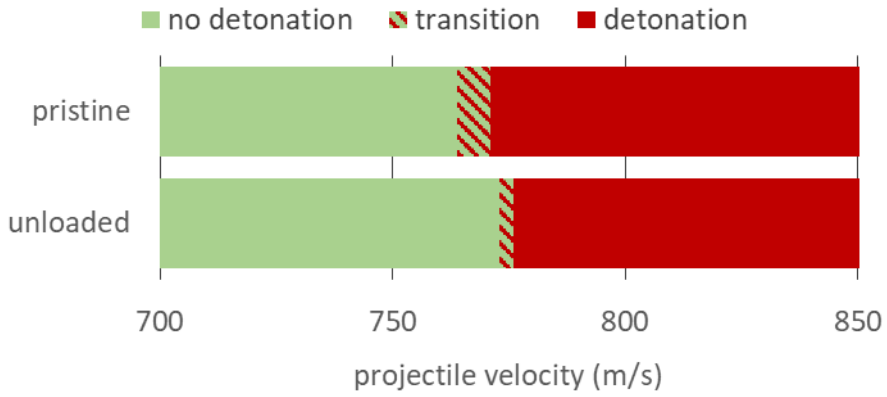
Shock Sensitivity Analysis – Small Scale Gap Test



- 180 days of thermal ageing do not increase the shock sensitivity
- additional 6 hours of mechanical loading seem to reduce shock sensitivity
- mechanical loading alters the mechanical sample properties:
  - deterioration of the sample structure at the cylinder ends
  - increased sample diameter
- questionable reliability of results

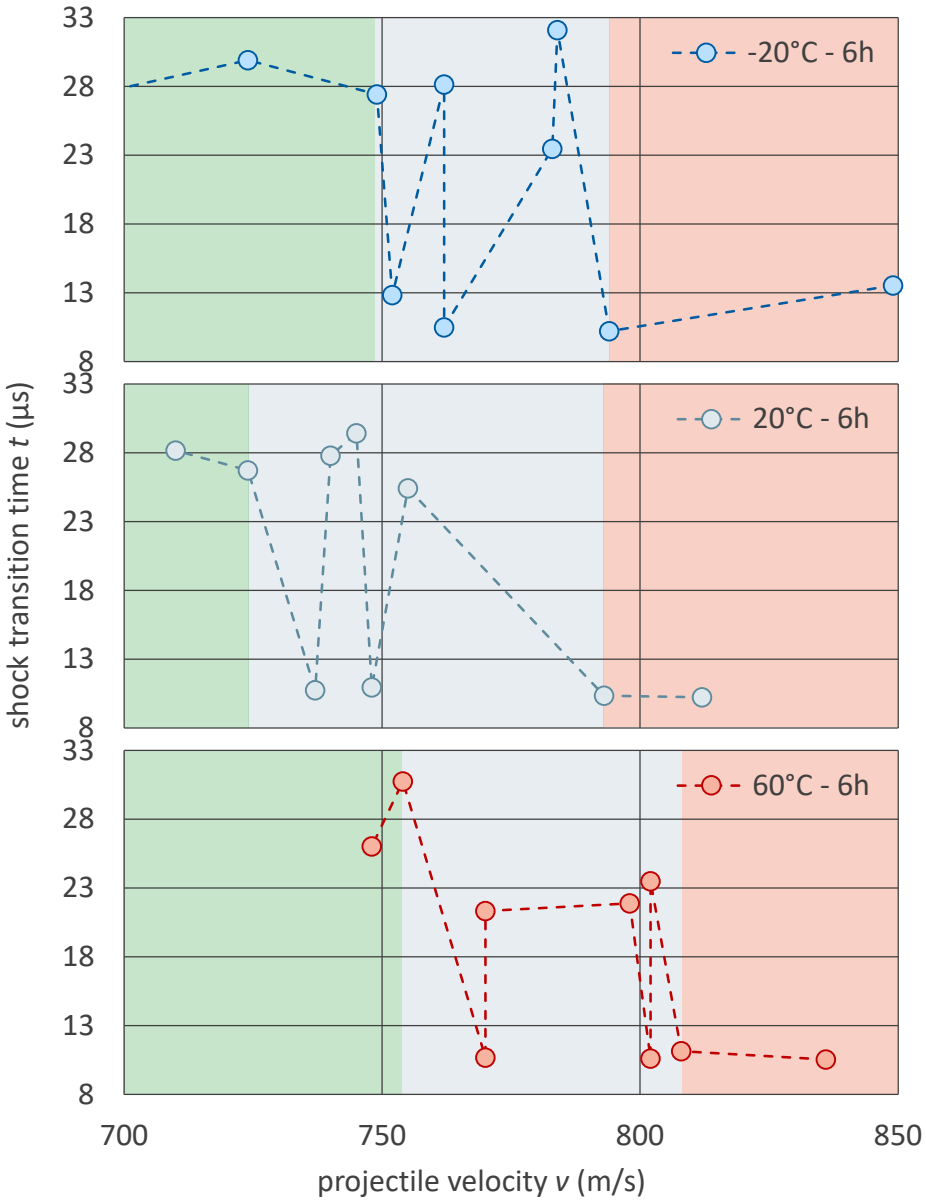
Shock Sensitivity Analysis – Projectile Impact Test





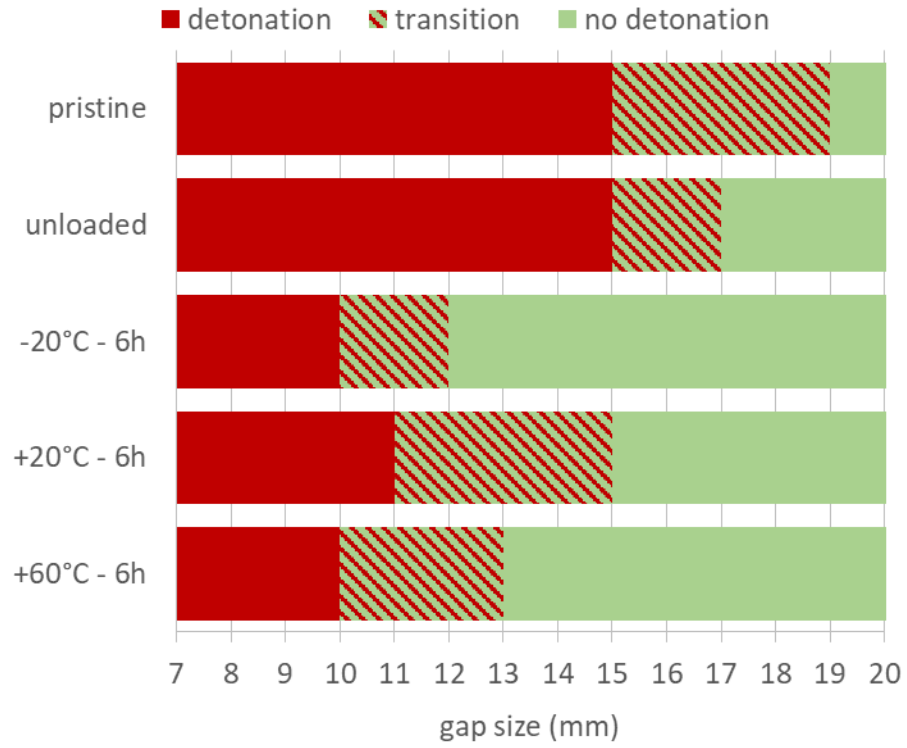
➢ 180 days of thermal ageing do not increase the sensitivity to shock

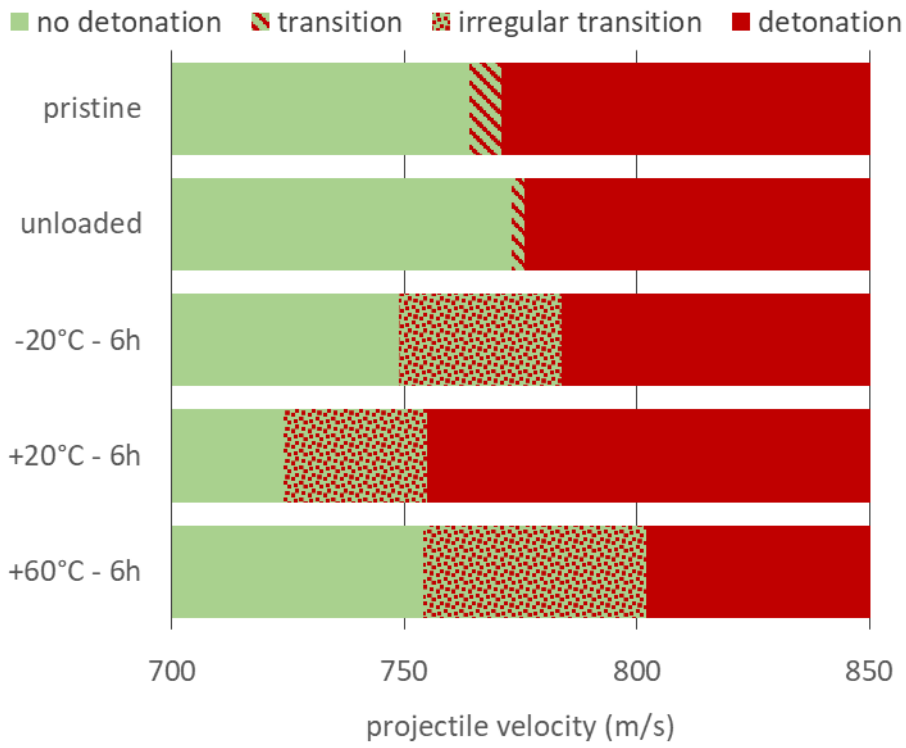
Shock Sensitivity Analysis – Projectile Impact Test



- mechanical loading leads to increased sensitivity to shock
- the transition zone is untypically irregular after mechanical loading

Shock Sensitivity Analysis – Summary & Conclusion





- inconsistent results for sensitivity after mechanical loading
- irregular transition regime!
  - sample structure altered by vibrations?
  - internal defects in the binder-filler system?

Outlook

- new project for next year focusing on mechanically loaded PBX samples
- additional high-resolution µ-CT investigations on the microstructure

ISL

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