Synthesis on EDA project on Insensitive Munitions & Ageing

Insensitive Munitions & Energetic Materials Technology Symposium

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Context

What about IM label, during ammunition life cycle?

Is it reasonable to consider it is <u>unchanged</u>

after 10, 20 or more years?

➔ Final goal

- To have **an overall methodology** able to predict if an IM signature assessed on pristine ammunition can be kept all along its life cycle

➔ IMA project objective

- To investigate ageing effects on EM vulnerability characteristics, considering factors such as:
  - Vulnerability behaviour (insensitiveness properties changes …),
  - Mechanical properties,
  - Chemical properties…

Outline

➔ IMA cooperation

- Project structure
- Project program

➔ French Ageing Program

- Energetic Materials / Tests selection
- Ageing conditions / Program schedule
- Experimental results
    - Data synthesis
    - Focus on mechanical results / friability results
- Validation tests

➔ Cooperation main results

➔ Conclusions and Perspectives

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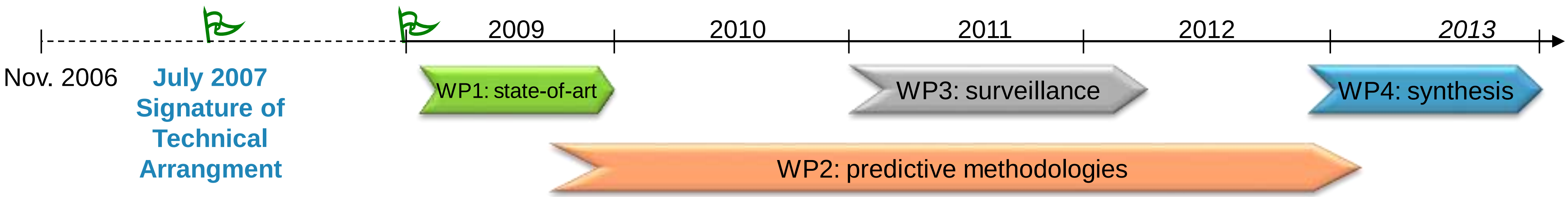
IMA cooperation

Project Structuring and Management

- **7 Contributing Members**
  - Czech Republic
  - Germany
  - Finland
  - France (leader)
  - the Netherlands
  - Sweden
  - United Kingdom

EDA European Defence Agency

- **Technical management :** 4 Work Packages



- **Duration ➔** 4 years extended to 5 years

Project Structuring and Management

➔ Large scope

- of energetic materials
- of ageing assessment experimental setup

Country	EM type	
CZ	explosive	Semtex® Pl SE M - Semtex® Pl SE M1
	rocket propellant	ROP - ROP1
	gun propellant	D370
DE	explosives	GAP bonded I-RDX
	component	I-RDX
FI	explosive	(FPX7) - FOXIT
FR	rocket propellant	HTPB /PA/Al
	explosive	B2214 - PBXN109
NL	explosive	KS32 - HU45 - HU51
SE	explosive	HMX/HTPB
	gun propellant	NL007
		NL008
		Uniflex 2 IM

Trials	CZ	DE	FI	FR	NL	SE
DMA		✓	✓	✓	✓	
tensile (dilatometer)					✓	
Hopkinson bar				✓		
X-ray tomography						
X-ray		✓				
Sol-gel (cross-link density)				✓		
thermal sensitivity test	✓	✓	✓	✓	✓	✓
shock sensitivity test	✓	✓		✓	✓	✓
NMR			✓			
HPLC-GCMS	✓	✓	✓			✓
FTIR		✓	✓			✓
mechanical tests	✓		✓			✓
ballistic impact chamber					✓	
slow cook off				✓	✓	
fast cook off				✓	✓	✓
fragment impact				✓	✓	
bullet impact	✓			✓		✓
steven test					✓	✓
safety tests		✓		✓	✓	✓
friability				✓	✓	
optical test		✓				

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French ageing program definition

Experimental program definition

➔ Focus on 3 different Energetic Materials

- A Rocket propellant, used in tactical applications
- 2 cast PBX compositions, included in general purpose bombs, mortar shells…

	EM	Rocket propellant	Explosive A (B 2214)	Explosive B (PBXN 109)
Id Data	Lot number			
	Production year	2008	2008	2008
	Manufacturing place	CRB	EURENCO Sorgues	EURENCO Sorgues
Composition	Binder (HTPB)	14 %	16 %	16 %
	Aluminum	4 %		20 %
	AP	82 %		
	NTO		72 %	
	HMX		12 %	
	I-RDX®			64 %
	Various additives are included in the binders (including plasticizer, cross linking agents, antioxidant and ballistic modifier)			

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Experimental program definition

➔ **HERAKLES and DGA (French MoD) have decided to focus on 3 different Energetic Materials, IM and Ageing properties : 2 explosives and 1 propellant**

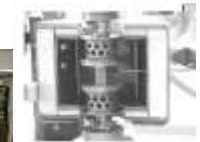
- Test performed : Mechanical properties, sensitivity and reaction violence tests (thermal threats / bullet impact / detonics)

EM	Mechanical		Thermal threat (FH / SH)		Bullet impact			Sympathetic reaction
Test	Uniaxial tensile test	DMA	DTA	Small scale SH test	Friction sensitivity	Friability	High Pressure combustion	GAP test (micro size)
Propellant	X	X	X	X	X	X	X	
Expl. A	X	X	X		X	X	X	
Expl. B	X	X	X	X	X			X

Micro GAP test

Julius Peters Friction apparatus

Friability



DMA

- Ageing programs @ 2 ageing temperatures
  - Artificial acceleration @ +50°C (F=2)
  - Natural (equiv.) @ +20°C
- 2 types of conditionings, representative of EM real environment : Air and Nitrogen

Type of conditioning	Ageing T°	Year of program	Storage time	Time at forced ageing (in months)
REFERENCE (pristine samples)		0	0	**0**
Surface (Air)	+20°C	2	2	**24**
		4	4	**48**
	+50°C	0.25	2	**3**
		0.625	5	**7.5**
		1.5	12	**18**
		2.5	20	**30**
		3.3	26.6	**40**
In depth (Nitrogen)	+20°C	4	4	**48**
	+50°C	0.625	5	**7.5**
		1.5	12	**18**
		2.5	20	**30**
		3.3	26.6	**40**

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French experimental results (pristine & after ageing)

Data analysis

➔ Synthesis table of the ageing program

- The main evolution observed is on mechanical behavior, for the propellant.
- This important hardening of the EM leads to a significant desensitization to friction threats. Other desensitization (micro gap test) is observed for the explosive A, but in a more moderate way
- No severe impact of ageing on sensitivity / reactivity properties for both explosives

EM	Mechanical		Thermal threat (FH / SH)		Bullet impact			Sympathetic reaction
Test	Uniaxial Tensile test	DMA	DTA	Small scale SH test	Friction sensitivity	Friability	HP combustion	GAP test (micro size)
Propellant	↗↗	↗↗	→	→	↘	→	→	
Explosive A	→	→	→		→	→	→	
Explosive B	→	→	→	→	→			↘

XXX : loss (of property)

XXX : gain (of property)

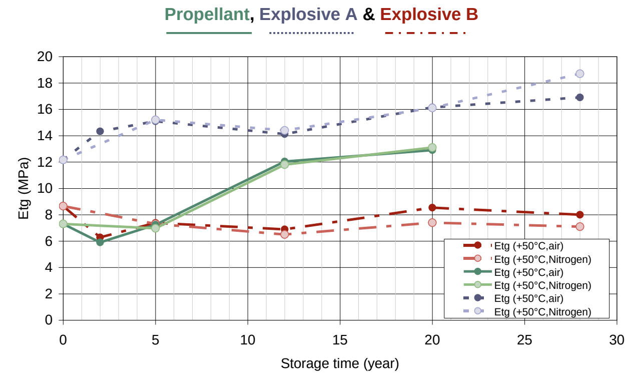
Main experimental results (pristine & after ageing)

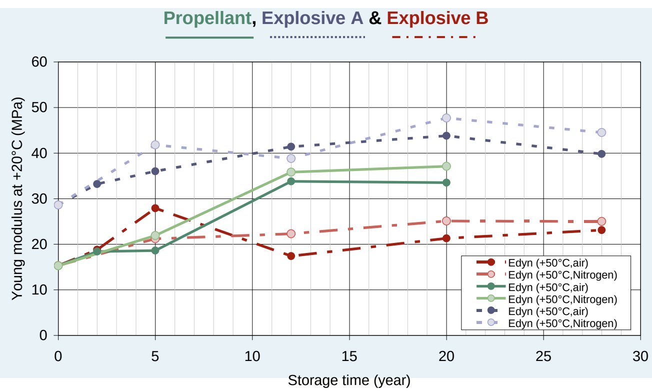
➔ Focus on mechanical tests

- **Tensile tests**

  (Strain rate @ 50 mm/min, Tamb., JANNAF dogbones samples)

  - Hardening of propellant on Young modulus
  - No evolution observed on PBXs after ageing
  - No difference seen between Air & N2 conditioning





- **DMA**

  (METRAVIB, T [+60°C → -90°C)

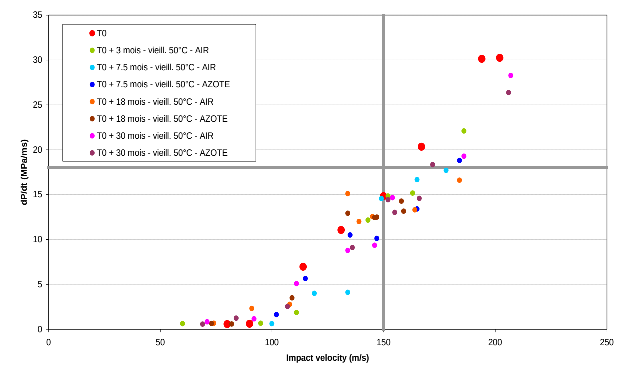
  - On HTPB propellant, 2nd peak (gel fraction transition) disappears & glass transition temperature is lowered after ageing → hardening of propellant on dynamical Young modulus (20°C)
  - No obvious change on PBXs after ageing
  - No difference seen between Air & Nitrogen conditioning

- **Friability test**

  (Impact velocity from 50 m/s up to 200 m/s)

  - No difference seen between Air & N2 conditioning
  - For both expl. B and HTPB rocket propellant, no obvious evolution is observed after ageing

    → attributed to measurement dispersion



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Main experimental results (pristine & after ageing)

➔ Validation mock up program

- Standard IM tests performed on non aged / aged EM, incorporated in representative structures (scaling up)

Threat / test / STANAG	Composition	Pristine test	Test after ageing (21 months @ 60°C)
SH, Slow Heating, @ 3.3 °C/h STANAG 4382	**Rocket propellant**	**Type IV**	**Type III**
	Expl. B	**Type III**	**Type IV**
FI, Fragment Impact, conical ended cylinder of 18,6g @ 1830m/s STANAG 4496	**Rocket propellant**	**Type III-IV**	**Type III-IV**
	Expl. A	**Type V**	**Type V**
BI, Bullet Impact, 0.5" armour-piercing bullet @ 850m/s STANAG 4241	**Expl. A**	No reaction **Type VI**	**Type V**

FI : Fragments of propellant & mock up metallic structure

➔ No direct impact of forced ageing observed on IM properties (BI, FI & SH) for all 3 EM, even after 28 years equivalent ageing (in good accordance with ageing programme results)

French conclusions & perspectives

→ Conclusions

- A large database has been built, with safety / vulnerability characteristics, depending on ageing conditions.
- Significant influence of ageing observed on propellant mechanical properties, i.e significant hardening.
- Progressive desensitization of the propellant for friction and explosive B for intense shocks threats.
- No severe impact of ageing on vulnerability for all 3 studied EM → this was observed both on safety characteristics (thermal, chemical, ballistic ...) and mock-ups test
- These data have been successfully incorporated in HKS numerical models (pristine results) for IM prediction.

→ Perspectives

- Friability data analysis method need to be more investigated, and correlated to mechanical data, for a better integration in numerical tools.
- Not only EM should be studied, system environment should also be taken into account, in a very next step

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IMA Conclusions and Perspectives

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Conclusions and perspectives of IMA Project

➔ **IMA phase 1**

- Project based on a large scope of energetics materials and tests
- A large data base available after this first phase

➔ **Main nations agree to keep on working on this topic as soon as possible**

➔ **Recommendations and further work**

- Mid term
  - Limit the scope to 1 to 3 energetic materials and to relevant tests – same for each nation ➔ more extensive data to be analyzed, with parameters variability study
  - Friability data analysis method should be reinvestigated vs mechanical data
  - Include additional loads: mechanical vibrations and temperature cycling
- Long term
  - Not only EM should be studied, system environment should also be taken into account, in a very next step
  - Surveillance
    - Forces have to be actively involved → real needs / problems to be reported
    - More accurate data from operational theater to be collected and further analyze

➔ **More details were presented at the 41st ICT conference (June 2014)**

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