MUNITIONS VULNERABILITY ASSESSMENT ALONG THEIR LIFE CYCLE - METHODS & RESULTS -

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INTRODUCTION

- The required service can reach 20 years for munitions (warheads, bombs, shaped charges, torpedoes, underwater mines, etc...).

- This paper aims at giving methodological tools and examples for IMness assessment according to their life cycle.

- Only few specific studies have been conducted to detect potential changes on IM signature.

- Some results are available concerning Cast Cured PBXs which are manufactured by EURENCO France.

- Two ageing conditions were used: 20 & 60°C during 11 & 8 years respectively.

PREDICTIVE METHODOLOGIES AND ANALYSIS TOOLS 1

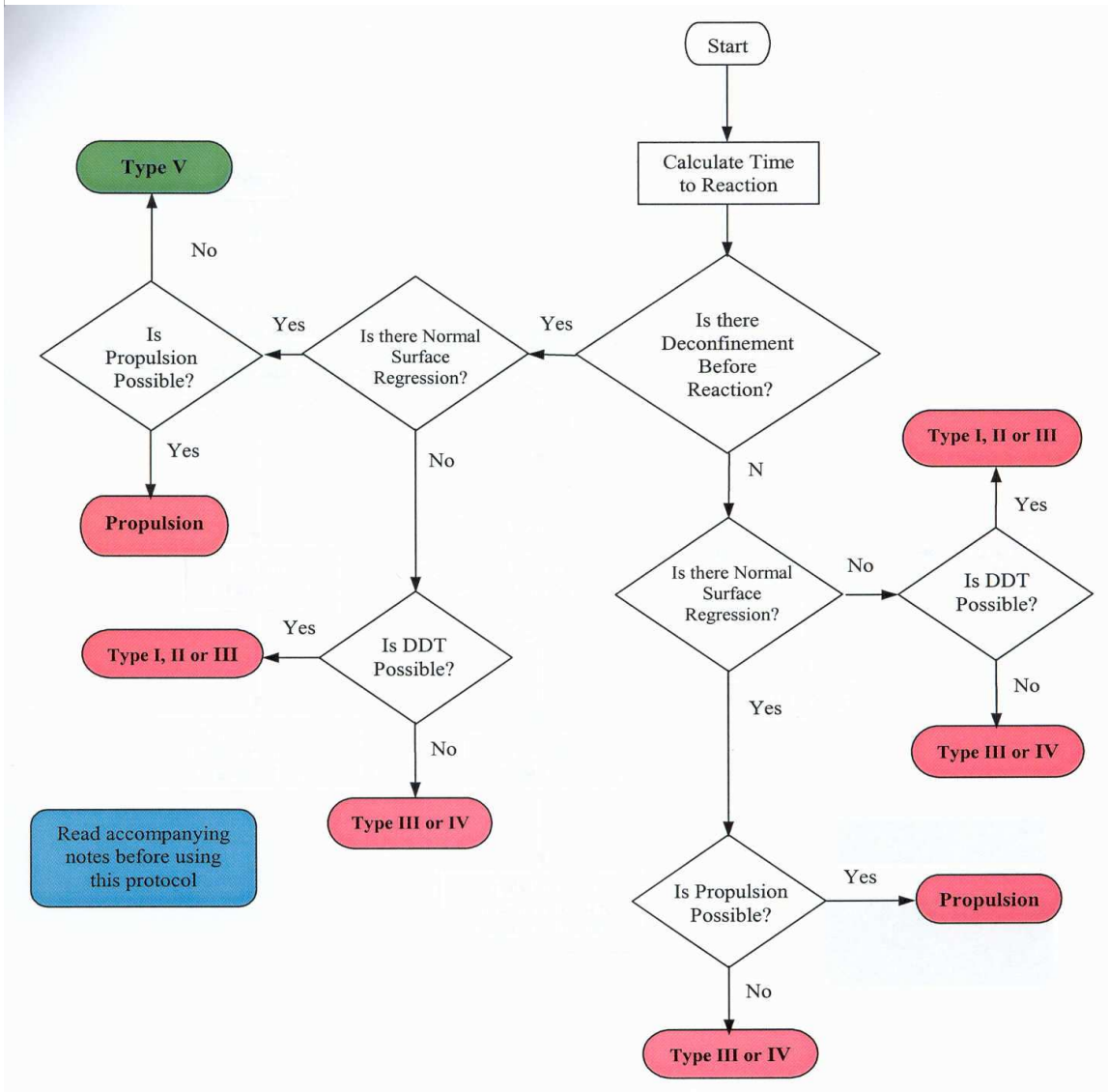
- The predictive methodologies are based on small scale trials and on databases associated to numerical simulations.

- It is done in the aim to reduce the number of full scale tests and to increase confidence in their results by the influence analysis of parameters.

- They are more or less precise according to the state-of-art, but they have been validated up to the full scale test for each vulnerability threat.

- These methodologies are recognized by French authorities DGA / IPE through vulnerability reports issued to obtain the MURAT Labels: 1, 2 or 3 stars (the 3 stars label is compliant with full requirements of STANAG 4439).

PREDICTIVE METHODOLOGIES AND ANALYSIS TOOLS 2



These methodologies are conceived to answer to all questions.

For example, "is DDT possible?" forces to consider when an EM grain is damaged by threat:

- Which is its specific surface?
- Which is its burning surface?
- Which is pressure increasing rate?
- Which is confinement pressure burst? - …

VULNERABILITY MONITORING PARAMETERS 1

- Previous protocol shows that it is necessary to have the knowledge of each elementary mechanism concerning EM reactivity and case properties in the aim to predict munitions responses.

- Fault Tree Analysis is useful to list these "vulnerability monitoring parameters".

- When this work has been achieved, it is possible to determine on samples the effect of ageing and to extrapolate to munitions IM signature.

VULNERABILITY MONITORING PARAMETERS 2

Munitions parts	Monitoring Parameters	Comments
Munitions case	Thermal conductivity	Thermal aspects
	Radiative emissivity	Especially for Fast Cook-off
	Pressure burst at high loading rates according to temperature	For all threats
	Shock Hugoniot	For intense shocks
	Melt temperature	Especially for Fast Cook-off
Thermal insulation / liner	Specific heat	Thermal aspects
	Shock Hugoniot	For intense shocks
	Melt temperature	Especially for Fast Cook-off
	Flammability temperature	Especially for Fast Cook-off
	Pyrolysis kinetic	Thermal aspects
Energetic materials (main charge, booster, …)	Density	
	Pressure / Time threshold for detonation	For intense shocks
	Detonation critical diameter	For intense shocks
	Friability	For all threats
	Pyrolysis kinetic	Thermal aspects
	Self-heating kinetic	For slow cook-off
	Pressure / Damage dependant burning rate	For all threats
Architecture parameters	Sticking resistance (case, thermal insulation, EM grain…)	
	Liquid tightness	Especially for melt cast explosives
	Protective cap characteristics	Nozzle, venting device
	Characteristics of mitigant devices	Functioning guarantee
	Characteristics of Ignition / initiation devices	Under all aspects

PROPERTIES STUDIES OF AGEING CAST CURED PBX 1

These characterizations were focused on classic mechanical properties and main safety characteristics as requested in NATO standards AOP 7 & 15.

The only vulnerability trials were the Bullet Impact tests which have been conducted on SNPE's vehicle (1.1 litres).

The ageing conditions were 20 & 60°C during up to 11 & 8 years respectively.

The PBX blocks were packaged in closed plastic bags.

Before experiments, samples were extracted by machining from block, avoiding to use the layers near from grain surface.

For Bullet impact tests the explosive grains were set up directly.

PROPERTIES STUDIES OF AGEING CAST CURED PBX $_2$

Studied compositions :

Purpose	Reference	Filler content	Binder	Filler (s)	Density	D (m/s)	EIDS
Booster	**B2188A**	84	HTPB	HMX/PETN	1.62	7900	No
	B2238A	78	HTPB	RDX	1.57	8040	No
Blast or underwater effects	**B2211D**	88	HTPB	RDX/AP/Al	1.81	5500	Yes
	B2245B	88	HTPB	RDX/NTO/AP/Al	1.81	5150	Yes
Ballistic effects	**ORA86B**	86	PU	HMX	1.70	8360	No
	B2214B	84	HTPB	HMX/NTO	1.63	7450	Yes
	HBu88A	88	HTPB	RDX	1.63	8110	No

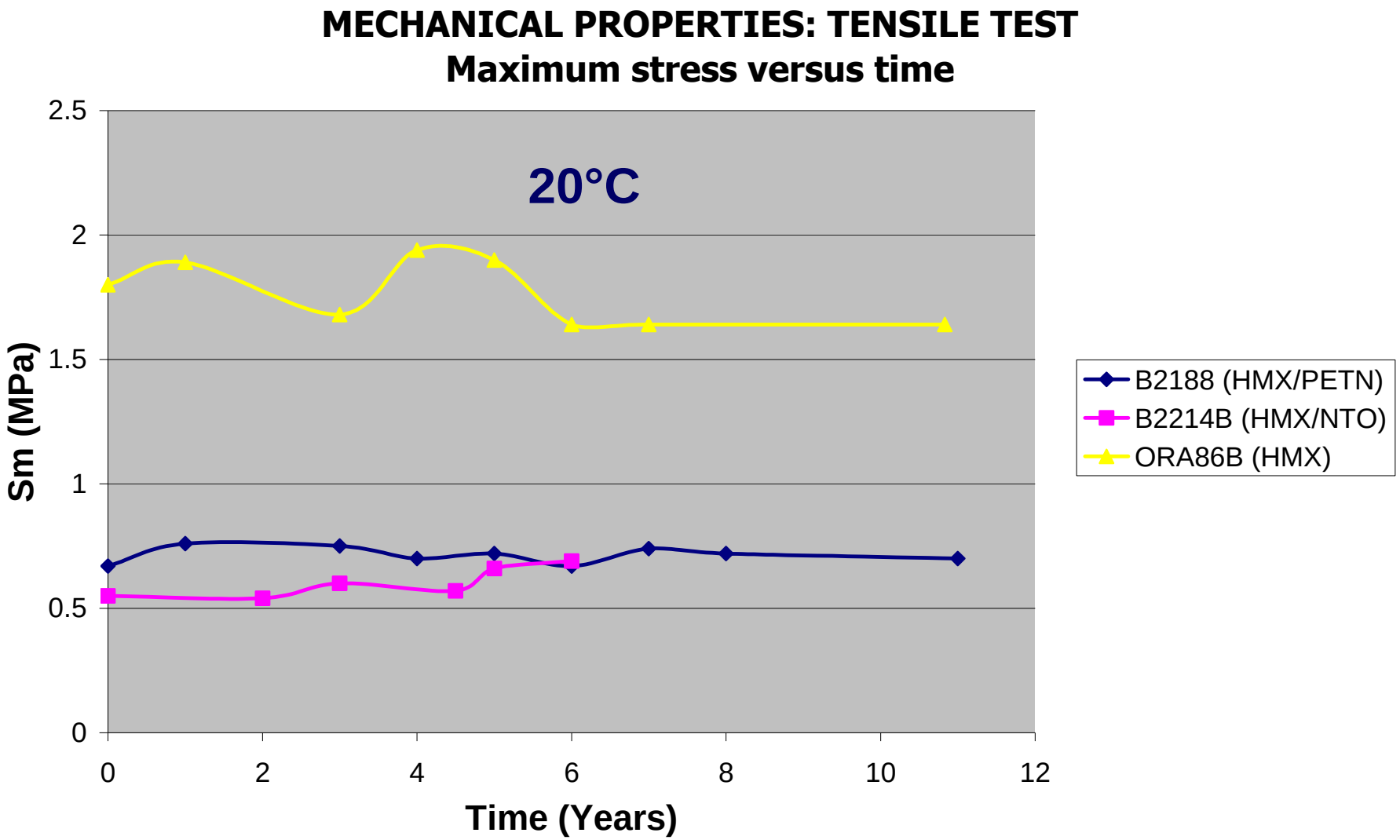
PROPERTIES STUDIES OF AGEING CAST CURED PBX $_3$

Mechanical properties :

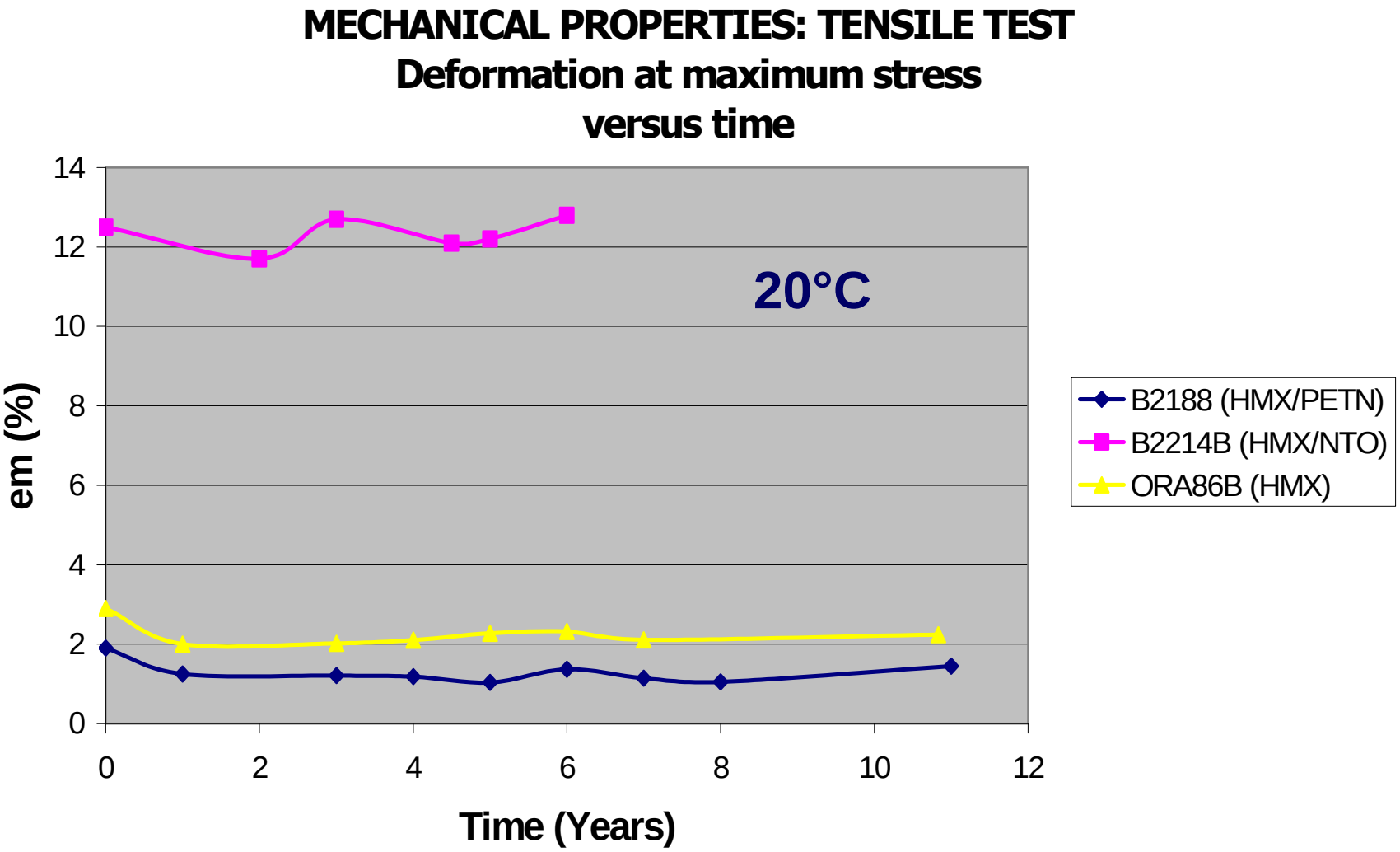
Uniaxial tensile according to AOP 7 STANAG 4506 with "dog bone" samples, crosshead of 50 mm/min, temperature 20°C.

Uniaxial compression according to AOP 7 STANAG 4443 with cubic samples (10 mm x 10 mm x 10 mm), crosshead of 1 mm/min, temperature 20°C.

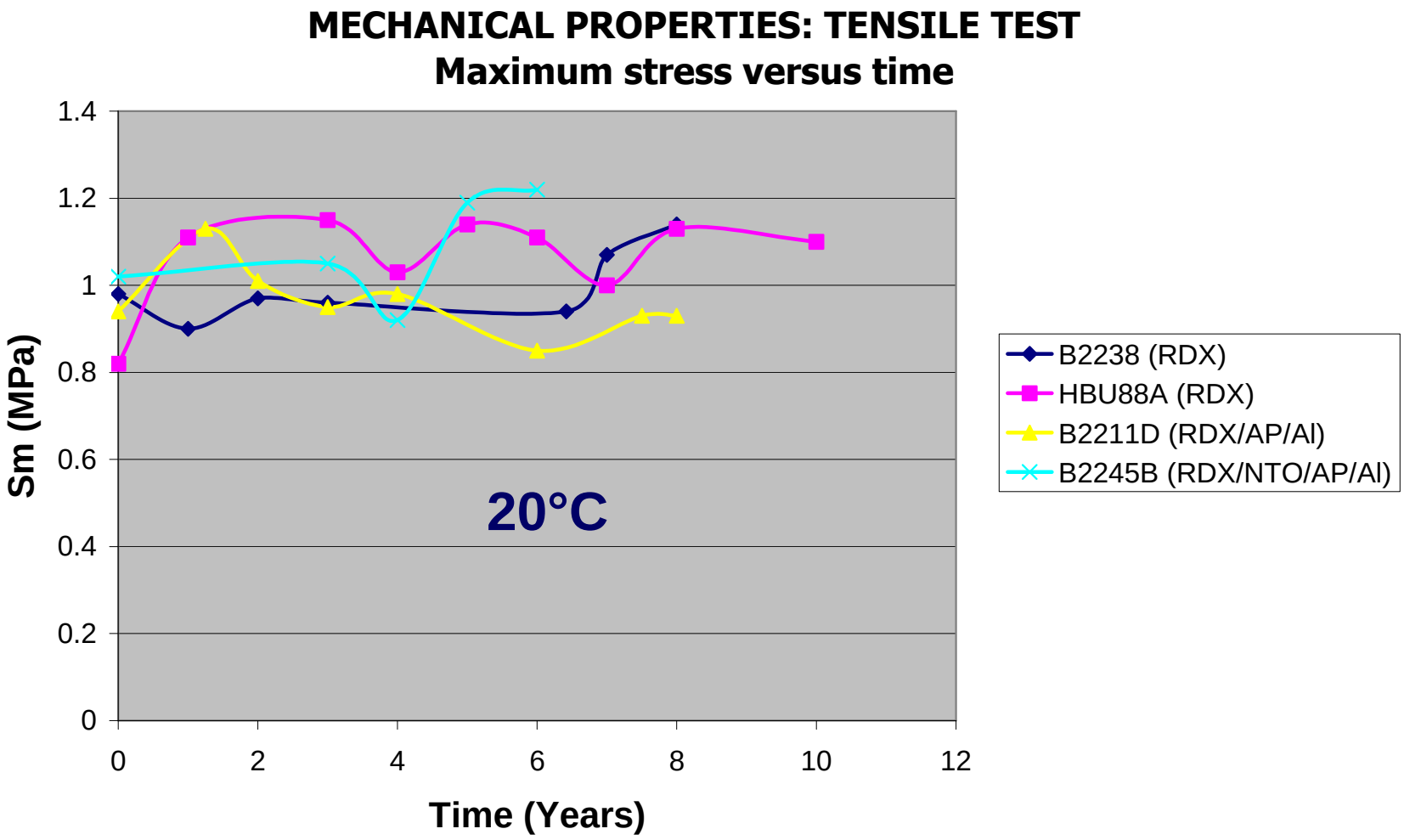
PROPERTIES STUDIES OF AGEING CAST CURED PBX 4



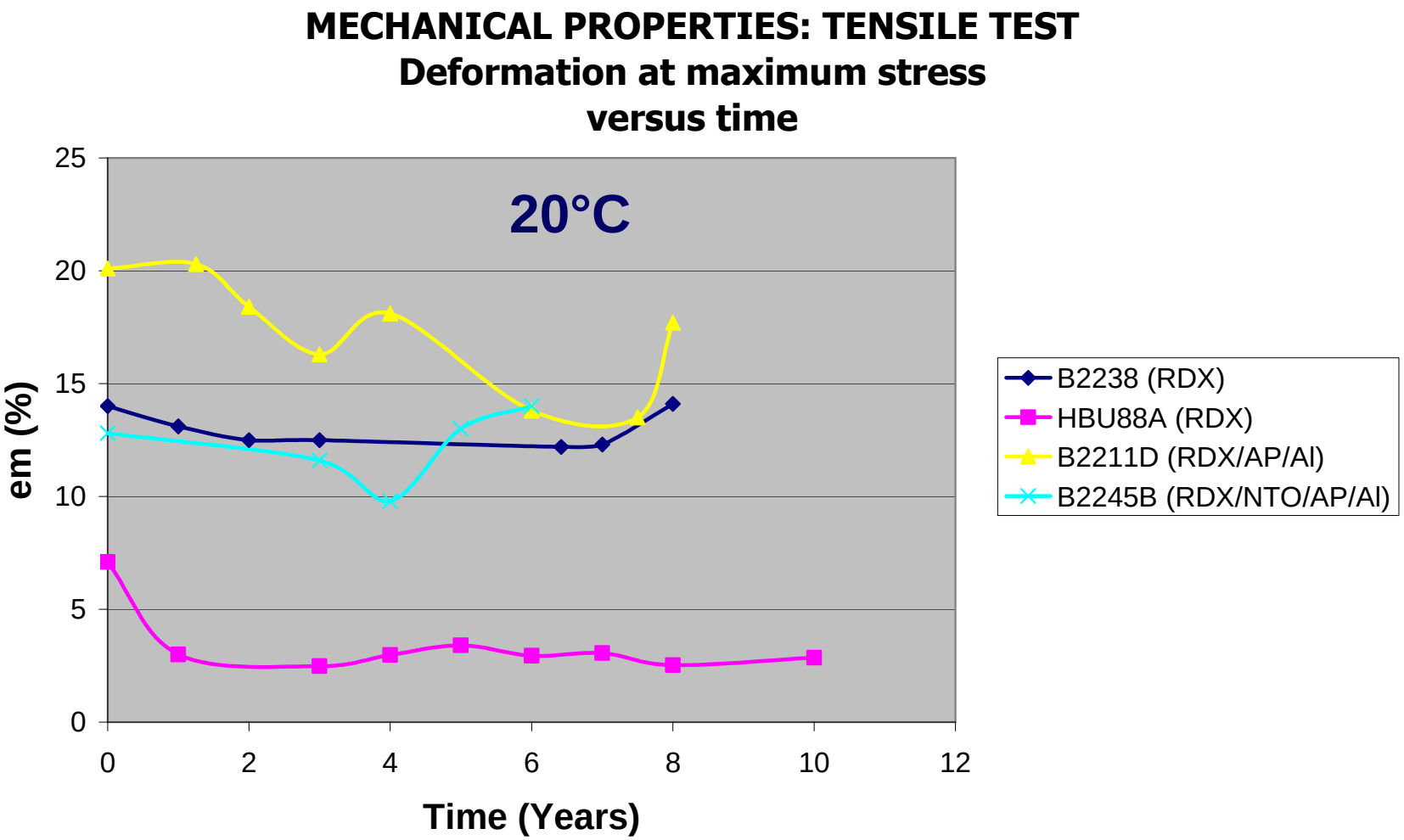
PROPERTIES STUDIES OF AGEING CAST CURED PBX 5



PROPERTIES STUDIES OF AGEING CAST CURED PBX 6

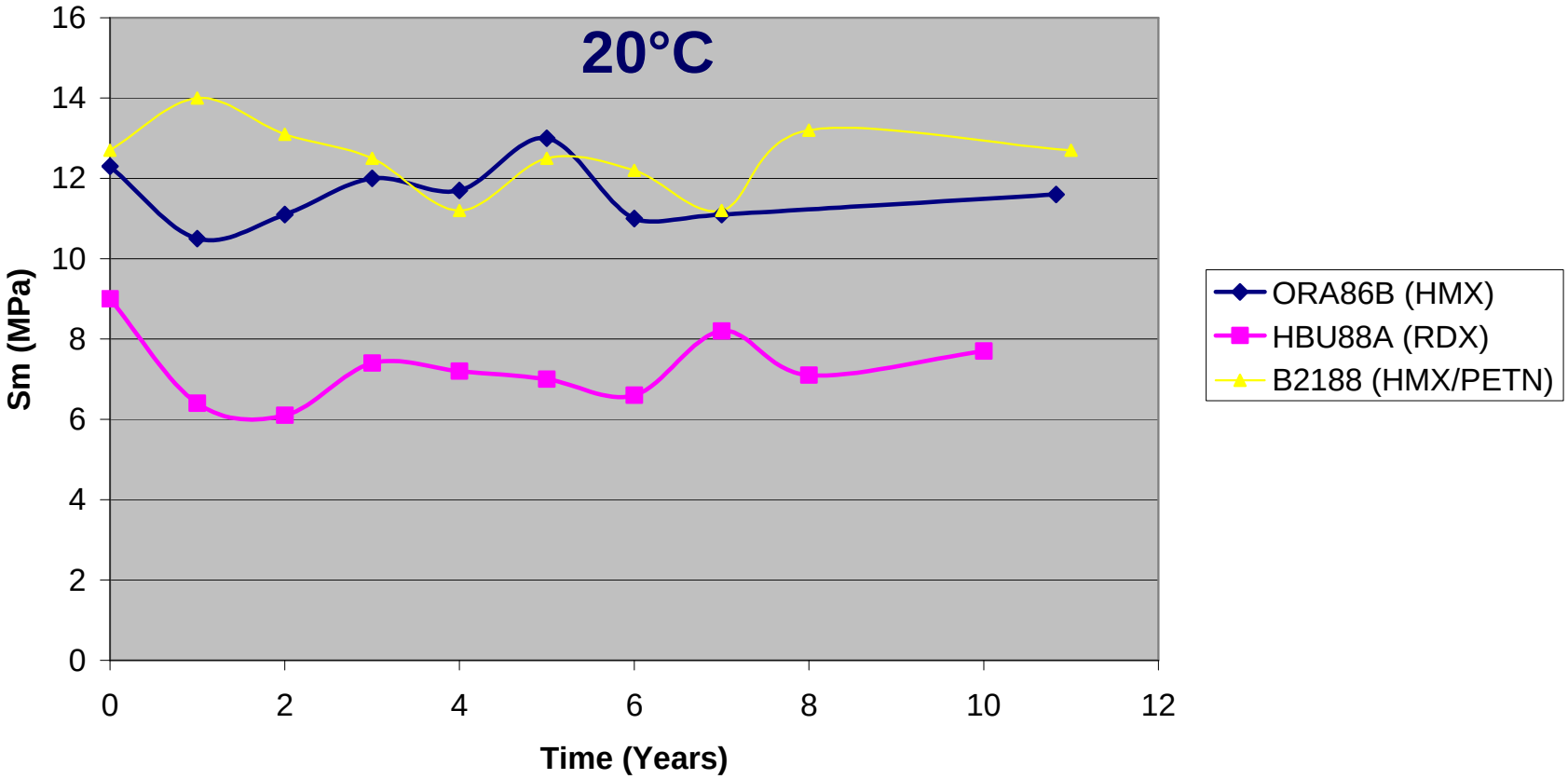


PROPERTIES STUDIES OF AGEING CAST CURED PBX 7



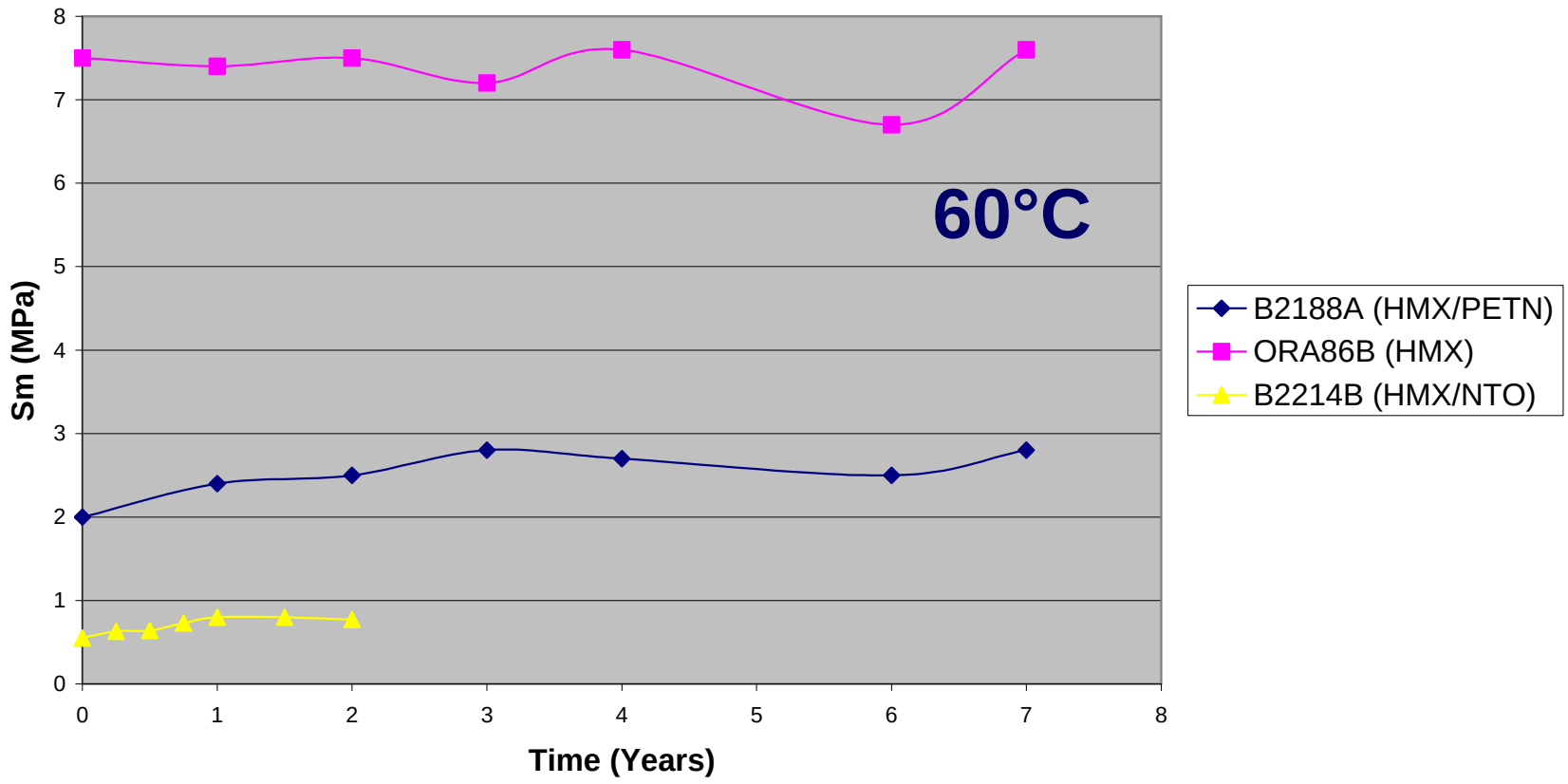
PROPERTIES STUDIES OF AGEING CAST CURED PBX 8

MECHANICAL PROPERTIES: COMPRESSION TEST
Maximum stress versus time



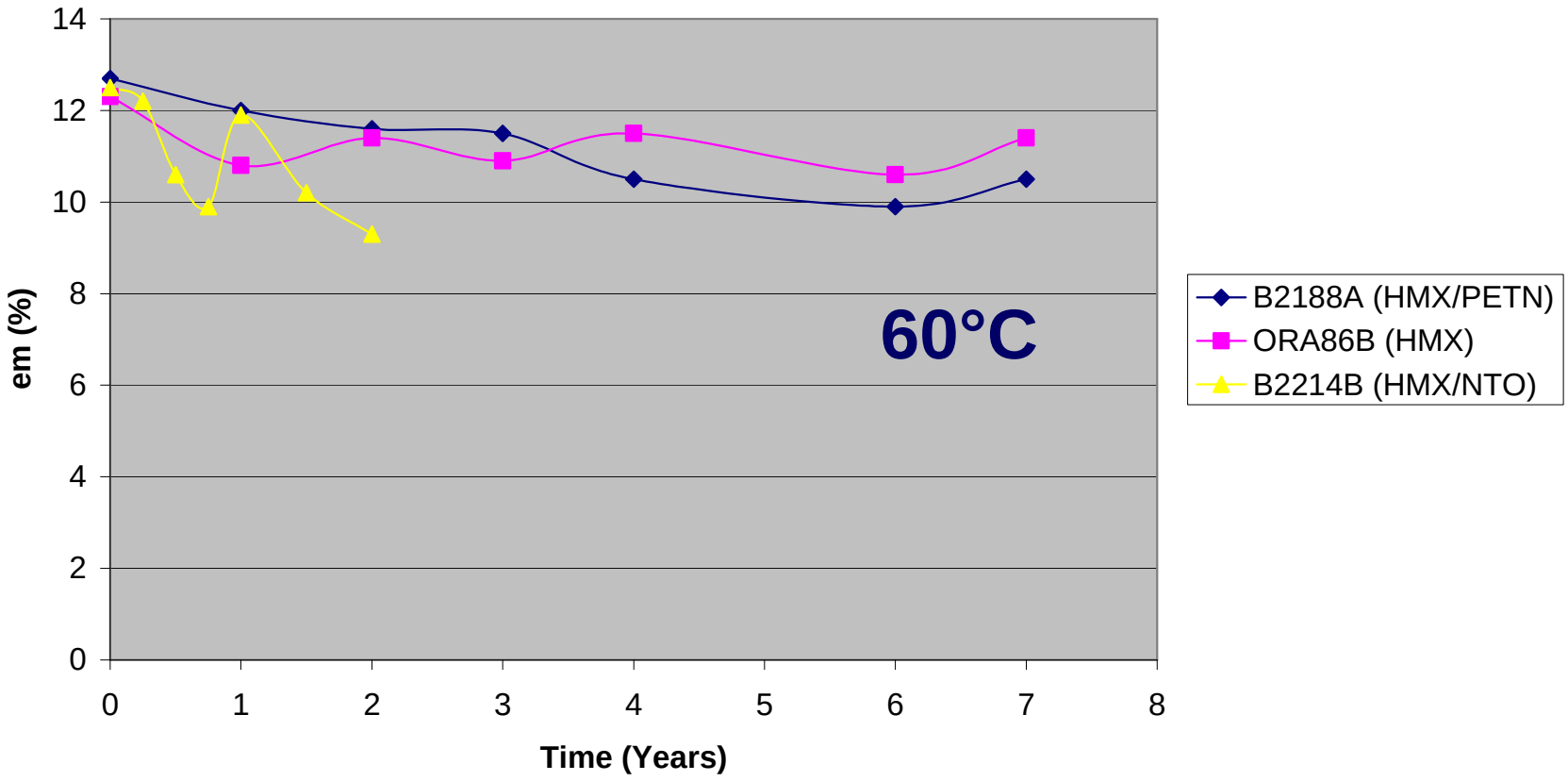
PROPERTIES STUDIES OF AGEING CAST CURED PBX 9

MECHANICAL PROPERTIES: COMPRESSION TEST
Maximum stress versus time



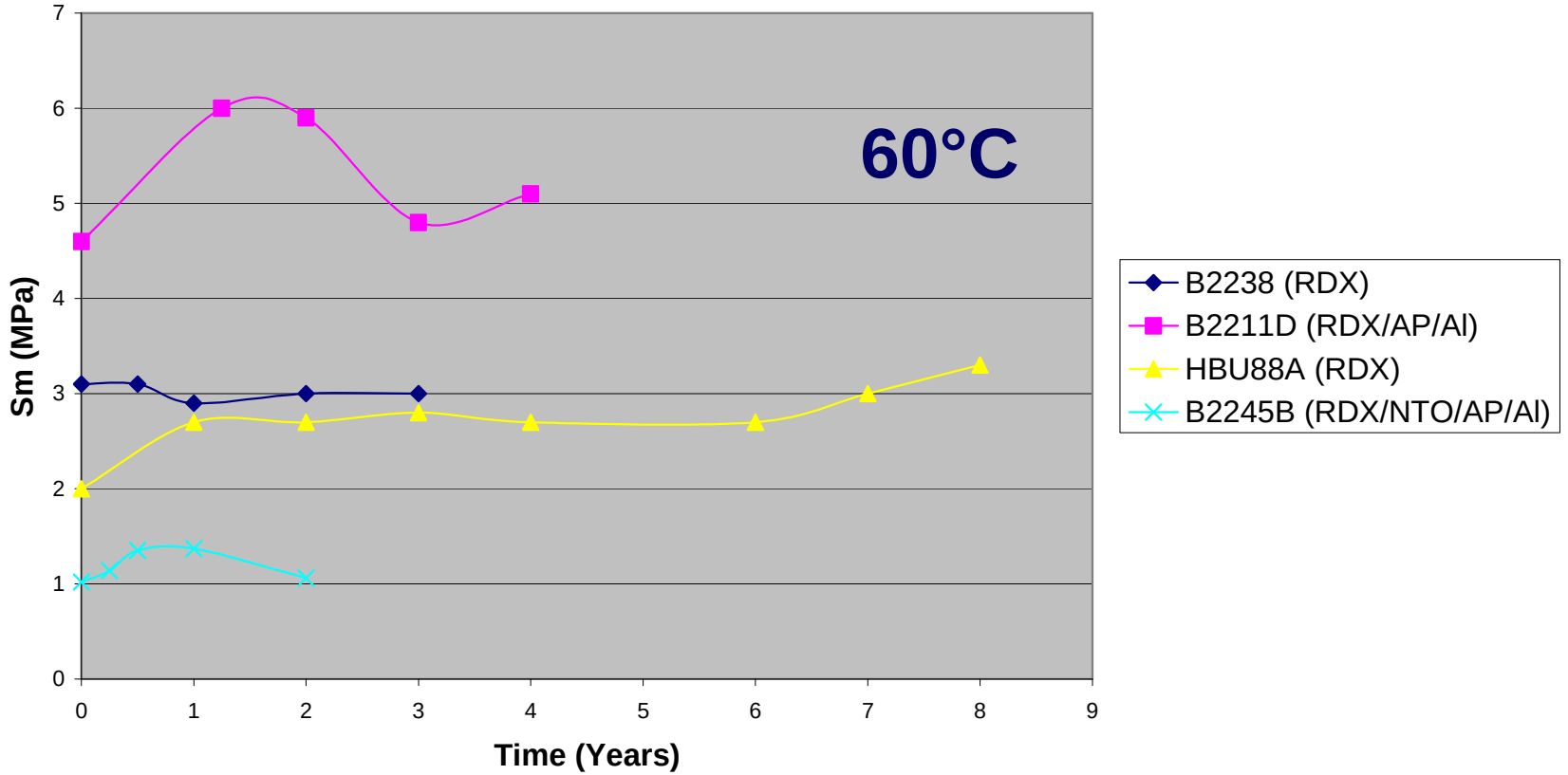
PROPERTIES STUDIES OF AGEING CAST CURED PBX 10

MECHANICAL PROPERTIES: COMPRESSION TEST
Deformation versus time



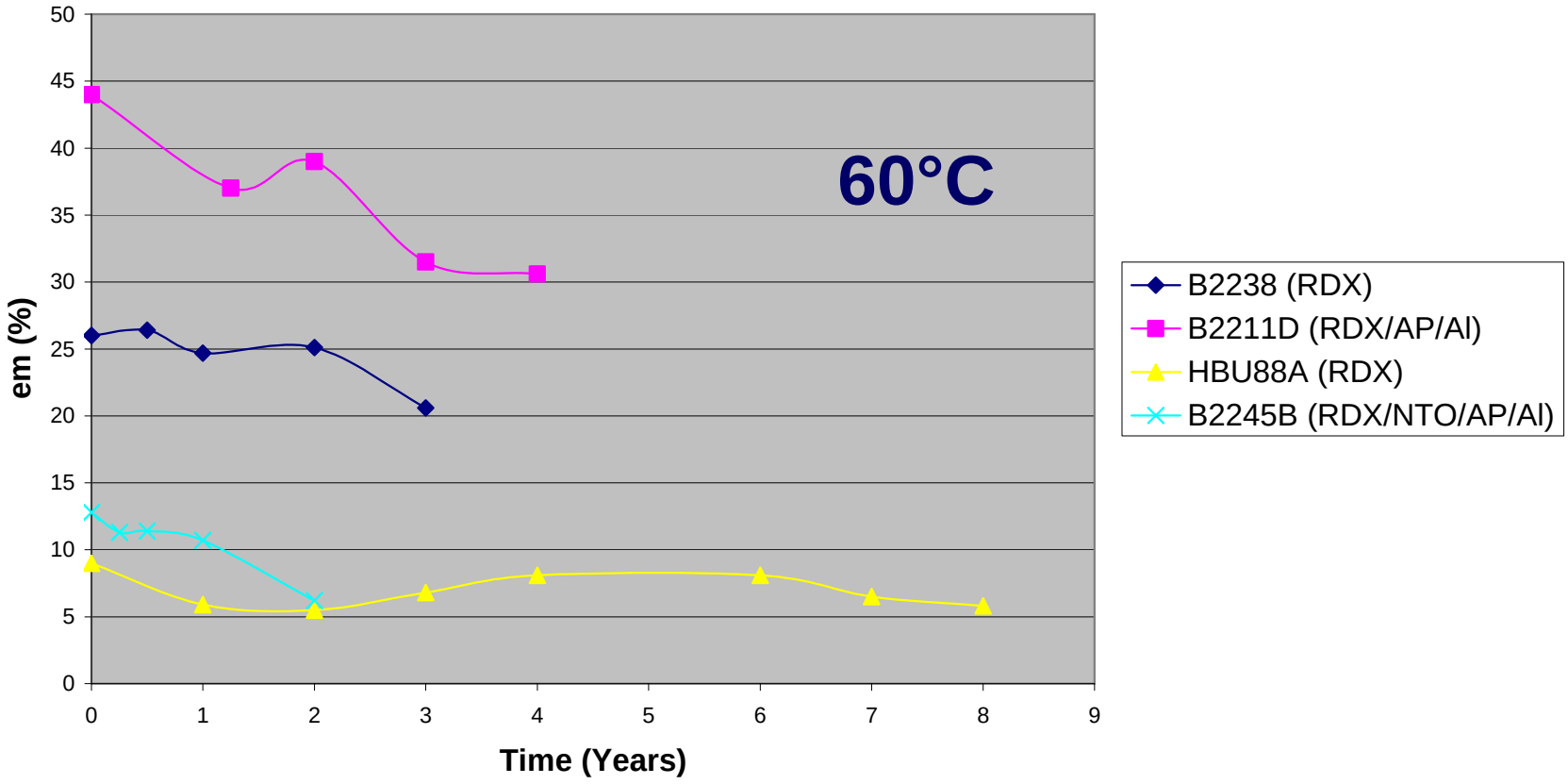
PROPERTIES STUDIES OF AGEING CAST CURED PBX

MECHANICAL PROPERTIES: COMPRESSION TEST
Maximum stress versus time



PROPERTIES STUDIES OF AGEING CAST CURED PBX 12

MECHANICAL PROPERTIES: COMPRESSION TEST
Deformation versus time



PROPERTIES STUDIES OF AGEING CAST CURED PBX

Safety and vulnerability tests:

- **Impact sensitivity (BAM) according to STANAG 4489C.**
- **Friction sensitivity (BAM) according to STANAG 4487A.**
- **Shock sensitivity (Intermediate Scale Gap Test) according to STANAG 4488B.**
- **Friability test according to AOP 7 (201.08.004) or UN 7c)ii).**
- **Combustion under high pressure: this test allows determining the pressure frontier between the layer by layer combustion propagation and cracking combustion which can outcome any deflagration-to-detonation transition. This frontier is called Break Pressure. It is performed in a closed vessel with a static resistance to rupture of 1000 MPa.**
- **12.7 mm bullet impact in vehicle according to AOP 7 (201.05.002).**

Safety and vulnerability tests:

Duration (years) at 20°C	Friability (dP/dt)max	Combustion under high pressure	Bullet impact (V = 850 m/s)
0	5	No pressure break	Pneumatic explosion
1	6.5	No pressure break	Pneumatic explosion
5	7.3	No pressure break	Pneumatic explosion
11	7.3	No pressure break	Pneumatic explosion
ORA 86 B : Effects on the friability, combustion and bullet impact tests			

PROPERTIES STUDIES OF AGEING CAST CURED PBX

Safety and vulnerability tests:

Time (years)		0	0.5	1	2	3	6	11
HBu88A	**20°C**	17		30		23	25.3	33.5
B2188A		18		22.5		22	23.1	20.0
B2211D		3.8		4.0			4.2	
B2238		2.5		3.2		3.8	3.6	
B2245		3.6					2.1	
B2245	**60°C**	3.6	4.0		3.7			
Effects on friability test: dP/dt_{max} (MPa/ms)								

PROPERTIES STUDIES OF AGEING CAST CURED PBX

Safety and vulnerability tests:

Time (years)		0	1	2	6	11
HBu88A	**20°C**	Pneumatic explosion	Pneumatic explosion		Pneumatic explosion	
B2188A		No reaction	Pneumatic explosion		Deflagration	Pneumatic explosion
B2211D		Pneumatic explosion	Pneumatic explosion		Pneumatic explosion.	
B2238		Pneumatic explosion	Pneumatic explosion		Pneumatic explosion	
B2245	**60°C**	Pneumatic explosion		Pneumatic explosion		
Effects on bullet impact test						

PROPERTIES STUDIES OF AGEING CAST CURED PBX

Experimental Characterizations:

Time (years)		0	1	2	6	11
HBu88B	**20°C**	No break	No break		No break	No break
B2188A		420	405		320	460
B2211D		No break	No break		No break	
B2238		No break	No break		No break	
B2245	**60°C**	No break		No break		
Effects on combustion under high pressure (MPa)						

CONCLUSIONS

- This paper presents many experimental results concerning the industrial Cast Cured PBX compositions.

- The compositions filled with RDX, HMX, HMX/NTO and HMX/PETN do not show significant variations of their mechanical properties during the ageing.

- The compositions filled with RDX/AP/Al and RDX/NTO/AP/Al present slight variations of mechanical properties, hardening or softening, which induce no evolution of the safety and Bullet Impact test results.

- This family of explosive compositions is particularly stable in the time and in temperature.

- Moreover, this paper presents methodologies allowing to predict munitions responses to each vulnerability trial taking into account the life cycles.