



End-of-life ammunition treatment and explosive recycling

Approaches and results

OCTOBER 15th 2025

End-of-life ammunition treatment and explosive recycling

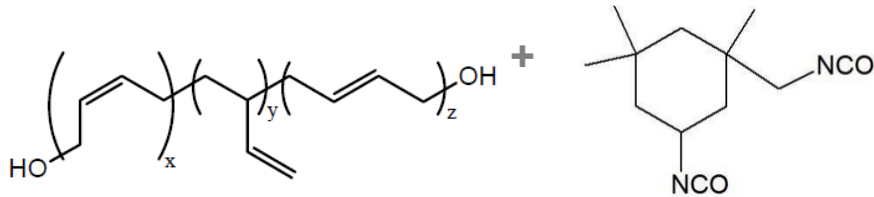
- ▶ Introduction
- ▶ Hypothesis definition
- ▶ Extraction and ammunition treatment
- ▶ Explosive recycling
- ▶ Conclusion and acknowledgment

End-of-life ammunition treatment and explosive recycling

- ▶ **Introduction**
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■ Project and context

→ Most of EURENCO cast PBX formulations use chemically cured binder based on Polybutadiene structure



→ HTPB based binders are very stable and durable but also difficult to degrade. It can become a disadvantage for ammunition at the end of service life

→ The main goal of this study was the development of a cast PBX:

- ❑ Suitable for industrial application,
- ❑ Chemically degradable,
- ❑ With possibility to extract the explosive under optimized conditions,
- ❑ And revalorise it to prove the feasibility of energetic fillers recycling



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▪ Hypothesis and concept validation

- Introduction of ester components in binder composition to increase the hydrolysing properties of the polymer
 - Development of a HMX based cast PBX formulation using ester components (Main polyol and plasticizer)

- Validation of hydrolysis concept on ester based binder
 - Hydrolysis treatment applied on cured composition
 - Extraction of a grey powder after filtration, washing and drying steps
 - ▶ 99% pure, undamaged,
 - ▶ No trace of binder,
 - ▶ No modification of thermal behaviour

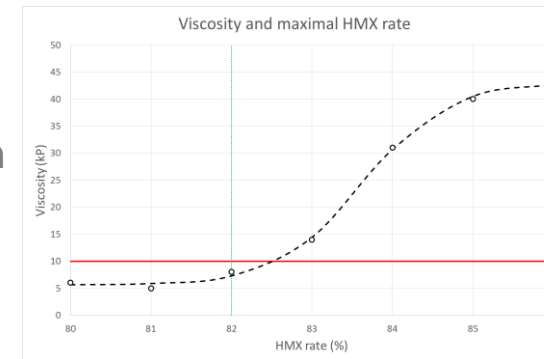
- ✔ → Validation of the concept of hydrolysis on ester based binder





▪ Hypothesis and concept validation

→ Formulation work at lab scale: Optimization of the processability and mechanical properties

- ❑ Best trade-off between HMX rate and viscosity defined:
Optimal HMX rate fixed at 82% for a viscosity < 10 kP
- ❑ Catalyst type and rate and binder composition fixed to obtain suitable chemical and mechanical properties



| Characteristics | Cast-PBX |
|--------------------|----------|
| Viscosity (P) | 5 300 |
| Hardness (Shore A) | 62 |
| Smt (MPa) | 0,50 |
| emt (%) | 14 |

-  → Definition of an optimized composition
-  but deterioration of hydrolysis conditions



▪ Hypothesis and concept validation

→ Optimization of hydrolysis treatment

- Parametric study conducted around different areas
 - ▶ Type and concentration of reagent
 - ▶ Temperature and duration of reaction
 - ▶ Ratio between reagents
 - ▶ ...

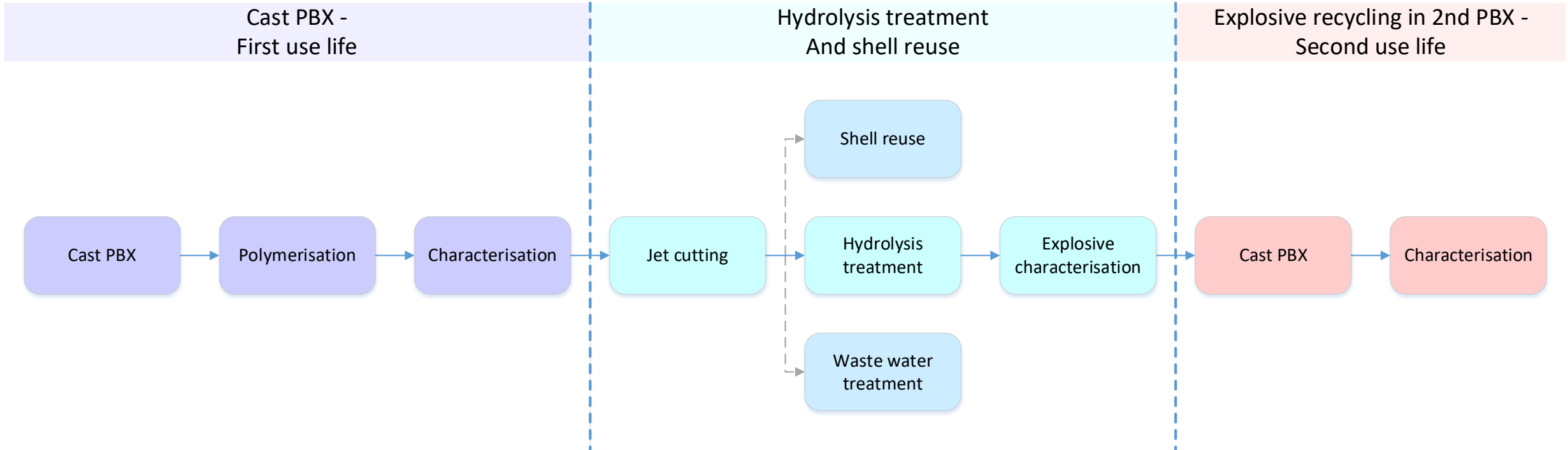
→ Definition of optimized hydrolysis parameters adapted to the composition

→ Hypothesis and concept validation

- ✓ Validation of the hydrolysis properties of a ester based binder
- ✓ Development of an ester based composition suitable for industrial application
- ✓ Optimization of the hydrolysis parameters to enable the extraction of the explosive for recycling



Recycling of explosive - Synoptic



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▪ Cast-PBX – 1st use life



→ Processing at industrial scale & characterisation

| | Characteristics | Cast-PBX |
|------------------------------------|---|----------|
| Chemical and Mechanical properties | Viscosity (Poises) | 6 000 |
| | Density (g/cm ³) | 1,714 |
| | Hardness, Shore A | 66 |
| | Stress maximum (MPa) | 0,50 |
| | Strain at maximum stress (%) | 13 |
| Safety and performance | Impact sensitivity (J) | 41 |
| | Friction sensitivity (N) | 353 |
| | Self-ignition temperature (°C) | 248 |
| | Shock sensitivity (number of cards) (STANAG 4488 – Annex B) | 160 |
| | Detonation velocity (m/s) | 8 200 |



→ Confirmation of the good properties and validation of the cast PBX based on ester components

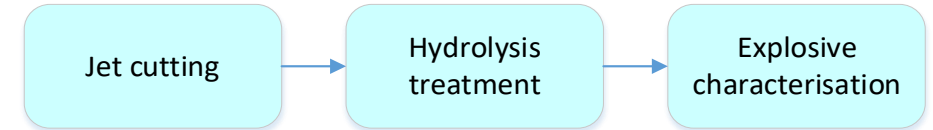
Hydrolysis treatment

→ Explosive extraction – A two-steps process

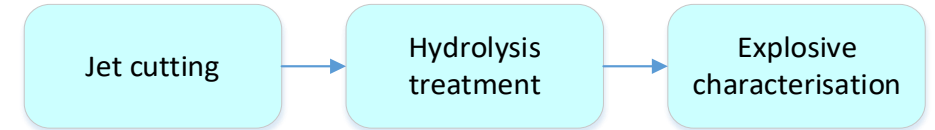
- Water jet cutting and filtration to extract composition from the shell
 - ▶ Analyse of the integrity of the ammunition
 - ▶ Treatment of the wastewater
- Hydrolysis treatment and filtration to extract the explosive from the composition



 → Validation of the hydrolysis concept



Hydrolysis treatment



→ Explosive characterisation

- ❑ Chemical and physical characteristics
 - ▶ Results within the specification, except for the acidity (due to the nature of the hydrolysis treatment)
- ❑ Particle size
 - ▶ Does not comply with any known class, corresponds to a blend of the different class initially introduced in the 1st cast-PBX
- ❑ Sensitivity
 - ▶ Comparison of the explosive sensitivity before and after hydrolysis

| | HMX post treatment | HMX crystalized – Average values |
|--------------------------------|--------------------|----------------------------------|
| Impact sensitivity (J) | 3,5 ± 0,3 | 5,1 |
| Friction sensitivity (N) | 174 ± 15 | 120 |
| Self-Ignition Temperature (°C) | 263 ± 4 | 269 |



→ Sensitivity acceptable

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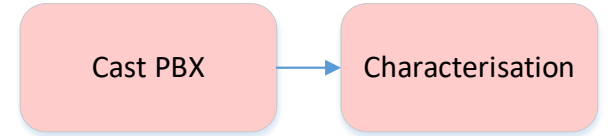
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Explosive recycling – 2nd use life

→ Processing at industrial scale & characterization

- ❑ Reduction of the loading rate for the best trade-off between higher explosive rate and processability
- ❑ Characterization

| | Characteristics | Cast-PBX |
|------------------------------------|--------------------------------|----------|
| Chemical and Mechanical properties | Density (g/cm ³) | 1,631 |
| | Hardness, Shore A | 80 |
| | Stress maximum (MPa) | 1,68 |
| | Strain at maximum stress (%) | 13 |
| Safety and performance | Impact sensitivity (J) | 35 |
| | Friction sensitivity (N) | 353 |
| | Self-ignition temperature (°C) | 253 |
| | Detonation velocity (m/s) | 8 100 |



 → Validation of the explosive recycling concept

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■ Conclusion

→ Based on literature, it is possible to degrade a cast-PBX binder based on ester components

→ Different trials made on a HMX based cast PBX formulation and the hydrolysis parameters led to:

- ❑ The development of a composition suitable for industrial application,
- ❑ The definition of a hydrolysis based treatment to degrade the binder and recover the explosive
- ❑ The validation of the explosive recycling concept



▪ References and acknowledgements

→ References:

- ❑ “Degradable and hydrolysable binder explosives”, B. Lee, Naval Air Warfare Center Weapons Division, China Lake, CA (08.1992),
- ❑ “Degradable and environment - responsive explosives”, B. Lee, R. Reed Naval Air Warfare Center Weapons Division, China Lake, CA (04.1996),
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**Thank you for your attention,
Questions?**