Urea Hydrogen Peroxide Detonation Performance

1. Introduction

Urea Hydrogen Peroxide (UHP) – Carbamide Peroxide:

- Commonly used in the cosmetic and pharmaceutical industries
- Easily manufactured from readily available household chemicals
- Explosive properties recently studied [1-2] : non-ideal, detonable at large scale

Scope of our research:

- Detonability of commercial lab grade UHP at the **100 g – scale**
- Determining detonation **performance parameters** for risk assessment purposes

2. Material and methods

- **Commercial lab grade UHP** (97%); 85% particles > 600 µm
- **Explo5**: Ideal detonation parameters & JWL coefficients for **Autodyn** modelling
- Need for **maximum experimental data**: lab & underwater measurements
  Detonation velocity (VoD), Detonation pressure (P_{det}),
  Equivalent shock (E_s) & bubble (E_b) energy

Lab firing:

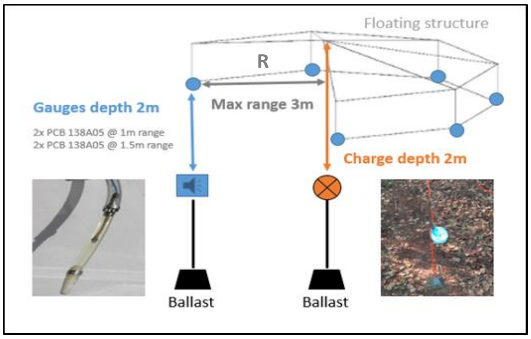
- 100 g cylindrical charges
- ID 30 mm, length 5 ID
- Heavy confinement (4 mm steel)
- Initiation by a standard N°8 military detonator and an 8 g C4 booster

Performance assessment: witness plate indentation and VoD measurements (Optimex 64), detonation pressure calculated from Cooper [3] from VoD and loading density

$$P_{det} = \rho_0 . (VoD)^2 . (1 - 0{,}7125 . \rho_0{}^{0{,}04})$$

Underwater firing:

- 100 g loose UHP spherical charges in plastic (PE) bags
- Initiation by a standard N°8 military detonator and an 8 g C4 booster
- 100 g C4 spherical charges fired for comparison



Performance assessment: brisance from underwater shock pressure and explosive power from bubble period (t_b)

3. Results and discussion

Lab firings results (theoretical predictions between brackets)

UHP loading density [g/cm³]	0.75	1	1.1
Average VoD [m/s]	2897 (3657)	3647 (4774)	3860 (5215)
Calculated Pdet [GPa]	1.86 (2.42)	3.82 (5.48)	4.67 (6.92)
Average indent depth [mm]	5.1 (5.5)	7.1 (8.5)	7.8 (9.5)
Relative brisance vs TNT [%]	9	18	22
Relative brisance vs C4 [%]	6.5	13	16
Relative brisance vs ANFO [%]	28	58	71

- Differences between the calculated and the experimental **velocities of detonation** between 750 and 1300 m/s, highlighting the non-ideal behaviour of UHP in these conditions [4]
- Calculated **detonation pressures** up to 33% lower than the predictions from the thermodynamic code Explo5 and the resulting indentations of the witness plate up to 20% lower than the simulated ones, especially at growing densities

Underwater results at R=1m (theoretical predictions between brackets)

	ρ [g/cm³]	m [g]	P_{max} [MPa]	t_b [ms]	E_s [Pa²s]	E_{sw} [MJ/kg]	E_b [s³]	E_{bw} [MJ/kg]
C4	1.63	100	21.45 (21.47)	121.5	11097 (11090)	0.929161 (0.928603)	0.0018	1.9735
UHP	0.75	100	8 (13.02)	80.7	1170 (5450)	0.097968 (0.456347)	0.0005	0.5784

- UHP: **highly non-ideal behaviour** with experimental data significantly lower than the value from our Autodyn model (60% P_{max}, 20% shock energy equivalent)
- **Autodyn model** based on CJ state ideal parameters calculated from Explo5, more suitable for military explosives, such as C4
- Calculated **equivalencies** (from TNT literature data):

Underwater explosions – TNT equivalencies [%]

Charge	Brisance	Explosive Power
UHP	13	33
C4	129	105

4. Conclusions and future work

- **Detonation performance of UHP** at the 100 g -scale has been characterised.
- Lab results confirmed self-sustained detonation under heavy confinement, with observed detonation velocities consistent with literature values from large-scale field experiments.
- TNT equivalents were calculated based on experimental results and compared to those obtained by theoretical prediction.
- UHP explosive power and brisance were quantified from bubble period and underwater shock pressure, with respective TNT equivalencies of 33% and 13%. This latter shock energy equivalent from underwater explosions is consistent with UHP relative brisance calculated from lab firing.
- Performing such an **experimental campaign** has proven useful to characterise the performances of non-ideal explosives for risk assessment purposes.
- **Future work** includes further assessment of booster contribution on total energy and a size-effect study, firing kg-size UHP charges underwater using the same scaled distances.

References

[1] A.K. Hussein, Relative Explosive Strength of Some Explosive Mixtures Containing Urea and/or Peroxides, *Chinese Journal of Explosives & Propellants* 2016, *39 (5)*, 22-27.
[2] R. Matyas, Explosive Properties and Thermal Stability of Urea-Hydrogen Peroxide, *Propellants, Explosives, Pyrotechnics* 2017, *42 (2)*, 198-203.
[3] P. W. Cooper, Explosives Engineering, Wiley-VCH, New York, 1996, p 265.
[4] C.L. Mader, Numerical modeling of Explosives and Propellants, CRC Press, New York, 2008, pp 261-265.

Francis Halleux[1], Jean-François Pons[1], Ian Wilson[1], Romuald Van Riet[2], Bart Simoens[2], Michel H. Lefebvre[2]

[1] Cranfield University, Defence Academy, SN6 8LA Shrivenham, United Kingdom
[2] Department of Chemistry, Royal Military Academy, 1000 Brussels, Belgium

F.Halleux@cranfield.ac.uk