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SMALL-SCALE CHARACTERISATION OF UREA HYDROGEN PEROXIDE EXPLOSIVE PERFORMANCE USING HETERODYNE VELOCIMETRY

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ABSTRACT

Urea Hydrogen Peroxide (UHP) is widely available in the cosmetic and pharmaceutical industries. UHP exhibits the behaviour of a tertiary explosive and previous research from the same authors has highlighted its detonability at small-scale under heavy confinement. In this work, UHP performance parameters are further investigated by heterodyne velocimetry. A detonation pressure of 2.5 GPa for UHP at a mean density of 0.75 g/cm^3 has been determined using the impedance window method, corresponding to a 13% TNT equivalence for brisance. This result is consistent with calculation from empirical correlations. An average 3200 m/s detonation velocity was recorded using contact probes, in excellent agreement with measurements from passive optical probes. This small-scale experimental campaign, which is complementary to and consistent with previous research, has proven useful to characterise the performances of non-ideal explosives for risk assessment purposes.

Keywords: Urea Hydrogen Peroxide, Detonation, Heterodyne Velocimetry

1. INTRODUCTION

Urea Hydrogen Peroxide (UHP), also referred to as Carbamide Peroxide, is widely available in the cosmetic and pharmaceutical industries. UHP exhibits the behaviour of a tertiary explosive and is hence investigated for risk assessment purposes within the scope of potential homemade explosives (HME) emerging threats.

Previous research from the same authors has highlighted UHP detonability at small-scale under heavy confinement (see Figure 1.1).[1] In this configuration, detonation velocities (VoD) were recorded using passive optical probes and the results were consistent with literature value from large-scale experiments.[2]

Figure 1.1: Experimental setup (left), witness plate indentation (middle) and fragmentation pattern (right).

The brisance of UHP, which describes its destructive shattering effect, was demonstrated by indent depth measurement on an aluminium witness plate, fragmentation pattern observation and fragments distribution analysis. Additionally, the detonation pressure (P_{det}) was estimated from an empirical correlation, using VoD and loading density (ρ_0).[3]

In this work, UHP P_{det} is further investigated in the same charge configuration by Heterodyne Velocimetry (Het-V), also referred to as Photonic Doppler Velocimetry (PDV). In a fact, Het-V is a powerful technique to observe materials under high dynamic pressure and carry out advanced detonics investigation, such as a direct measurement of the particle velocity at the interface between the explosive charge and an inert material whose shock properties are well documented.

2. MATERIAL AND METHODS

We used commercial lab grade UHP (97%) purchased from ALFA AESAR (85% of the particles > 600 µm) and the validated charge geometry (Inner Diameter 30 mm, Charge Length 150 mm), initiation train (8 g PE8 booster and N°8 standard military detonator) and confinement material (4 mm thick steel), which are extensively described in Reference 1. A total of 10 devices were fired

in the containment building of the Explosives Research and Demonstration Area (ERDA) at the Defence Academy of the United Kingdom. Eight devices were filled with approximately 80 g of loose UHP (ρ = 0.75 g/cm^3) and two devices contained 40 g PE8 (Chemring Energetics UK, VoD nominal 8000 m/s, ρ = 1.57 g/cm^3) for comparison.

Surface velocities were measured using a generation 1 heterodyne velocimeter. This instrument used a 1550 nm laser source, emitting laser light from a fibre-coupled collimator with a 75 mm working distance and a 220 µm spot size. The reflected (Doppler-shifted) light was mixed in the interferometer, and the intensity of the beat signal was amplified by a Thor Labs PDA-8GS photodetector. The electrical output from the photodetector was recorded using a Tektronix 6 GHz bandwidth oscilloscope, sampling at 5 GS/s. The instrument used in these firings provided two independent channels, recorded on the same time-base. Each velocity record was processed using a Hamming window Fourier transform with variable window width, to produce a time-resolved power spectrum image. This was manually digitised to produce numerical time-velocity data for analysis in Microsoft Excel.

Het-V was primarily used to measure P_{det} by the impedance window method (IWM).[4] The first channel was directed at the interface between the end of the test specimen and the polymethylmethacrylate (PMMA) impedance window, to record the motion of this interface. Different PMMA window thicknesses (2.8 mm, 9.5 mm) and mirror interface types (first Aluminium spray painted, then reflective foil to get stronger reflection) were tested. Detonation pressure was calculated from IWM data by impedance matching across the explosive-inert interface.

The second channel was directed normal to the cylindrical surface of the confining cylinder, to record radial expansion of the cylinder driven by the reaction products from the test specimen. The metal acceleration by explosives is typically studied using the cylinder expansion test with thin pure copper cylinders. However, this confinement is unlikely to be strong enough to allow UHP detonation to develop in this charge configuration.[2] From the initial metal acceleration, we calculated the maximum radial pressure for comparison.

The progress of the reaction wave (VoD) was recorded by a linear array of 32 contact probes placed at a distance of 2.0 mm parallel to the surface of the cylinder. During the experiment, the collision of the grounded metal cylinder against the contact probes provided measurement of the position of the confining cylinder as a function of time. The contact probes were spaced 1.27 mm apart, measuring the wave progress over a distance of 40 mm; the last probe was positioned approximately 10 mm from the end of the cylinder closest to the impedance window. Probe contacts were recorded on an Intronix 32-channels logic analyser, sampling at 200 MHz, and hence giving a contact time resolution of 5 ns. Probe data were tabulated in Microsoft Excel, to produce a plot of probe distance as a function of contact arrival time. The slope of a linear best fit line through the data provided a measurement of the steady propagation

velocity of the reaction wave. The results were compared to previous measurements with passive optical probes.

Figure 2.1 gives an overview of the experimental setup.

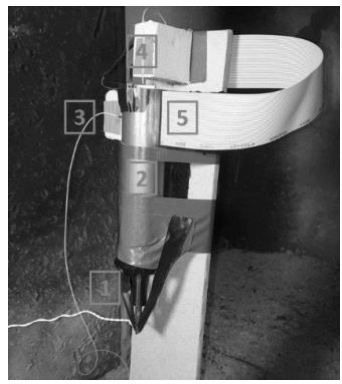

Figure 2.1: Experimental setup – Initiation (1), Explosive charge in steel sleeve (2), Het-V probe for cylinder expansion (3), Het-V probe for impedance window (4), VoD ribbon cable probes (5).

3. RESULTS AND DISCUSSION

An overview of the measured explosive performance data is available in Table 3.1.

Table 3.1: Measured explosive performance data.

Detonation Velocity (average)	m/s	3200
Detonation Pressure	GPa	2.5
Maximum Radial Pressure	GPa	4

In this charge configuration, we could record an average 3200 m/s VoD for UHP at a 0.75 g/cm^3 density, which is consistent with previous measurements using passive optical probes.

As far as P_{det} measurement is concerned, the first five shots with PMMA impedance windows glued to the steel sleeve were unsuccessful. Because the shock propagates faster in the steel confinement than the detonation front in UHP, the PMMA plate was already moving, disrupting the setup, which gave unusable power spectrum. The use of a PMMA impedance window (10 mm by 10 mm) placed on the UHP particles bed, avoiding any contact with the steel sleeve, provided improved signals.

This was particularly true for the particle velocity profile at the interface UHP/PMMA, obtained from a 2.8 mm thick PMMA window (Figure 3.1). The obtained signal shows, as expected, some velocity scatter due to the heterogeneity of the explosive. The duration of the signal is similar to the shock transition time through the PMMA, which is dependent on the pressure, typically

1-3 μs. After the shock transit, a second velocity trace appears which corresponds to the free surface velocity of the PMMA window, approximately twice the interface velocity.

Calculation of P_{det} by impedance matching across the explosive-inert interface provided an average 2.5 GPa (13% TNT equivalent for brisance), a value consistent with our previous work.

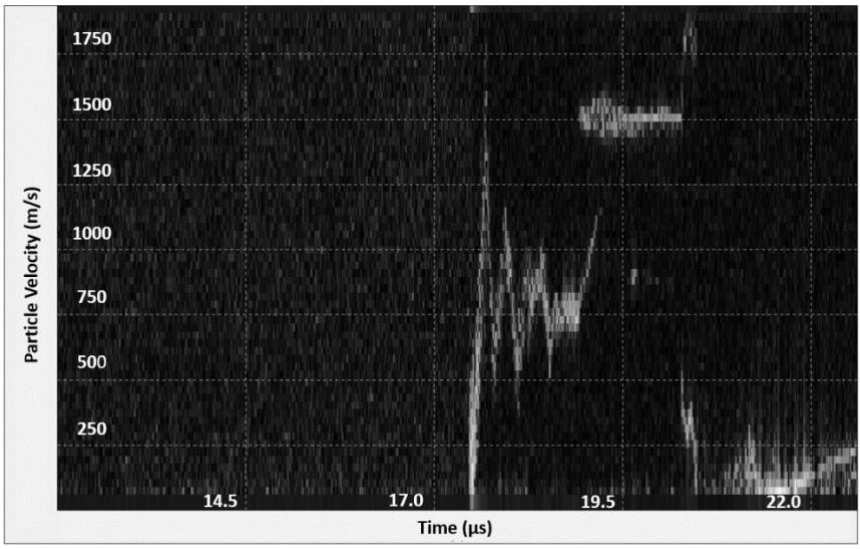

Figure 3.1: Power spectrum obtained for a single shot using a 2.8 mm thick PMMA window and reflective foil, giving an average 750 m/s at the interface with UHP.

Only one of three UHP tests with similar setups provided such a record, while the remaining tests only provided the PMMA upper free surface velocity trace. Impedance window experiments often fail with granular or coarse crystalline explosives, as highlighted by similar experiment[5] carried out on ANFO, especially if there is only a thin aluminium foil as a reflective layer. A 0.3 mm thick aluminium plate would be required to get at least some signal. Moreover, contact between UHP and the impedance window has to be improved, given the granular nature of the charge.

From the cylinder expansion records (see Figure 3.2), we determined an average maximum initial metal acceleration of 54 x 10^6 m/s^2, corresponding to a maximum radial pressure of 4 GPa.

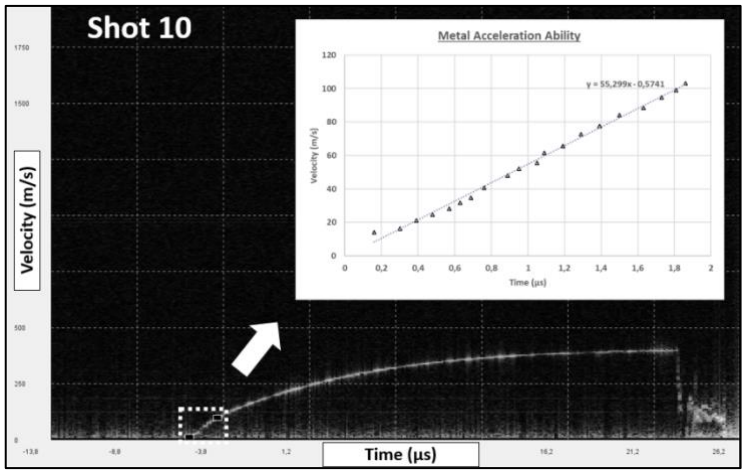

Figure 3.2: Initial metal acceleration from cylinder expansion – example shot 10.

4. CONCLUSION

A detonation pressure of 2.5 GPa for UHP has been measured using heterodyne velocimetry and applying the impedance window method. This value (13% TNT equivalent for brisance) is consistent with calculation from empirical correlation.

These are only preliminary results and future work includes improvements of the experimental setup, including hardware, in order to achieve accurate and reproducible measurement of detonation pressure, including error estimate.

This small-scale experimental campaign, which is complementary and consistent with previous research, has proven useful to characterise the performances of non-ideal explosives for risk assessment purposes.

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