DETONATION PHENOMENA OF PBX MICROSAMPLES

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Abstract. Detonation study of PBX micro-samples, based in HMX with an inert (HTPB, epoxy) or energetic (GAP) binder was performed on the meso-scale level, using the multifiber optical probes of 50 μm of maximum resolution, connected directly to a fast electronic streak camera with 0.6 ns resolution. The direct 2D observation of particle to particle successive transition of transmitted shock wave, through the binder, allows to analyse and to discuss, not only the cooperative formation of a multihead detonation front (DF), in the collection of particles surrounded by binder, but also the synenergetic effect, behind the DF, by the appearing of dissipative structures drawing spatial and temporal DF oscillations.

INTRODUCTION

Phenomena of pulsing detonation of PBX was originally mentioned in the experiments, carried out on the meso-scale level, as a result of the application of high resolution multi channel optical method, based on optical fiber strip. Phenomena of pulsing detonation, in chemically reacted media, implies that the initially smooth shock front, induced by the external source, losses its stability and it is followed by the origination of the oscillating structure (OS), behind the forward front (FF). OS appears as a result of the inter-influence, in the strongly non equilibrium zone within the FF and chemical reaction zone (CRZ), of a few relaxation phenomena: kinetic relaxation involving release of energy (due to the exothermic reactions), thermal dissipation (due to heat/mass transfer) and stress relaxation (due to the existing limit velocity of impulse/shock waves (SW) propagation).

Theoretically it was obtained that, independently of the physical nature of the energetic material, but according to the combination of different main relaxation times, in energy release and heat/mass transfer, and under the influence of the fluctuations), it can exist two main different kinds of detonation wave (DW) regimes, showing different unsteady spatial-temporal dissipative structures (DS).

These spatial-temporal DS are consequently the OS with the transversal SW (represented the cellular DW with the longitudinal-transversal DF oscillations) and OS without transversal waves, but with the additional longitudinal shocks (DF as a oscillating giant monocell). Characteristic sizes of DS depend on the EM physical/chemical properties and its rheology. We have detected both of these regimes in PBX.

The phenomenology of the origination and transformation of naturally unstable PBX detonation regimes has been already described, based on the experiments on the meso-scale level. The factor of divergence of the reactive flow behind the FF (specified by front curvature) was found to be the influential parameter determining the regimes of DW instabilities and DS. It is obvious that the increase of the divergence, in the reacting particles flow, will change the rate of relaxation, in strongly non-equilibrium temperature/stress fields, behind the FF. Micro-mechanisms of temperature-stress transfer are very important in the OS lateral phase formation. The kinetic relaxation level, in the
process of propagation in crystals of shock reactive wave [SRW], constitutes the governing factor determining the initial phase of OS origination. The existing delay of the energy release, in shocked and reacting crystals (in PBX, after the FF), could imply the changing of process of energy transfer and the pattern of non equilibrium temperature and stress fields, in CRZ.

The presented study concerns the evaluation of the relaxation phenomena of energy release and of the stress fields, associated with SW propagation in explosive crystals, by the direct registration of SW within single crystals and its clusters, under the similar conditions to the PBX detonation. This objective also implies the clarification of the complex pattern of the OS depending not only by particle sizes and its compaction but also by the binder nature (inert or reactive).

**EXPERIMENTS**

The experiments were carried out on the mesoscale level with the micro and mini samples of PBX, based on HMX crystals surrounded by polymer binders (HTPB, epoxy, GAP) or by water. The multifiber optical probes [MFOP] of the matrix type, with 250 μm of spatial resolution (50 μm maximum, in colimation mode), were connected directly to a fast electronic streak camera (THOMSON TSN 506N). The streak records, with 0.6 ns of maximum temporal resolution, allow the 2D and 3D analysis of SW and DW in PBX micro-samples and HMX crystals. This procedure allows the registration of, not only the emitted irradiation from the front surface (in SW propagation inside the μ-sample), but also the induced stress amplitudes and the front geometry (in thin layers of kapton), from the input and output SW.

**RESULTS AND DISCUSSION**

Non Monotonous Shock Reaction and Energy Release in Coarse HMX Crystals

Two experiments have been conducted for the direct time registration of the SW propagation in single coarse HMX crystals, surrounded HTPB binder (Figure 1) and by water (Figure 2).

**FIGURE 1.** Registration on the SW propagation in HMX crystal, surrounded by HTPB binder. (a) experimental set-up; b); c); and d) micro-photos of HMX crystal, matrix MFOP and the MFOP in the background of the crystal; e) photochronogram; f) z-t diagram and velocity of SW before, during and after the crystal; g) histogram of the relative intensity of the light emitted from the central zone of the propagated SW front.

The experimental results, presented in these figures, show the significant effects of the SW propagation inside the HMX crystal: 1 – The non monotonous built up and following decrease of SW velocity D, in order of the successive increasing and decreasing of the crystal cross section, followed by the enhance of the light emission intensity, at the end of the SW run. Pike of D corresponds to 2/3 of SW total run in the crystal; 2 – The delay time of the maximum stress phase, in the down kapton barrier, corresponding to the delay of the pike of energy release.; 3 – Anisotropic effect of the SF propagated through the binder, with the enhanced stress, not in the central, but in the preferential zone of the crystal/binder interface, proved by preferential development of SW in kapton barrier (Figure 2 e)).
The obtained results clarify the mechanism of relaxation of the HMX crystal reaction, induced by strong SW, proving the existing time delay in its energy release, behind the FF. The experimental time relaxation seems to be greater than the time needed for the shock propagation inside the crystal. Future developments will be focused to the quantitative evaluation of the ratio relaxation time vs. ignition delay.

Reactive Waves Propagation, Interaction and Transition in the Ensemble of HMX Crystals

These kind of experiments were performed with a collection of crystals, arranged in the vertical position, related to the initiating SW. Other results of experiments with horizontal clusters of HMX crystals, surrounded by HTPB and by GAP binders, show the significant role of the binders nature in the interaction process between the induced SW in the inter-crystal space. Performed tests show colliding SW’s, generating the strong reaction in GAP binder, generate a multi-head front less fluctuated (more homogeneous) that appears with the HTPB binder.

The results of the experiment with the vertical group of three HMX crystals, in the epoxy binder, are presented in Figure 3, showing the non-monotonous (pulsing) process of the SW propagation, inside the crystals, and its transition from crystal to crystal, through the 10-20 μm thick inter-particle space. The mean velocity of SW propagation, inside the crystal’s chain is estimated in 7.0 mm/μs, that exceeds in ≈1.4 times the SW velocity in the surrounding epoxy binder (but in ≈1.2 times less than the maximum velocity within the individual crystals).

From the presented results it can be concluded that the defined relaxation effect of the unstable kinetics of shock reaction of a single crystal, accompanied by the surface edge effect, shows the same essential properties that can be observed in the group of crystals, creating the conditions for high order of fluctuations of energy dissipation, behind the FF, followed by formation of the DS by the mechanism of the transversal micro shock interactions.
Experimental results confirm the synergetic effects in PBX detonation described in the past.

**CONCLUSIONS**

The detonation study of PBX on the meso-scale level has been carried out applying the high-resolution multi-fiber optical technique, in original tests, with single, two and more particles, surrounded by inert and energetic binders. The obtained results show the kinetic instability in shock reaction of coarse HMX crystals, surrounded by binder, the cooperative formation of a multihed detonation front (DF), in the collection of particles, and also the synergetic effect, behind the DF, by the appearing of dissipative structures with spatial and temporal DF oscillations.

**REFERENCES**