11th International Detonation Symposium,
Snowmass, Colorado,
August 31-September 4, 1998

DYNAMIC EQUATION OF STATE AND STRENGTH PROPERTIES OF UNREACTED PBXW-128 EXPLOSIVE

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Shock equation of state and strength data have been obtained on the explosive PBXW-128 over the pressure range 0-3 GPa using gun impact techniques and velocity interferometry diagnostics. Nonlinear shock-velocity-versus-particle velocity behavior is observed. Possible mechanisms are discussed and a Hugoniot equation of state model for the data is provided.

INTRODUCTION

The Navy explosive identified as PBXW-128 is a soft, rubbery solid comprised of approximately 60% by volume HMX powder in a polymer binder. In application this explosive is required to sustain relatively large shocks and undergo large deformations at high rates of strain without reacting. The design and optimization of systems including this explosive through computational simulations require accurate models describing the unreacting explosive material response to shock wave loading and high rate deformation.

The objective of the present study was to acquire shock wave equation of state (EOS) and dynamic strength data, and to develop material response models compatible with current production computational codes to describe PBXW-128 explosive. The current shock EOS and dynamic strength testing covered a previously uninvestigated shock pressure range between approximately 0.3 - 3.0 GPa. These new data complement earlier high-pressure shock wave data (Lindfors, 1997) and high-strain-rate Hopkinson bar data (John *et al.*, 1997; Tasker *et al.*, 1998).

The work performed in the present study is presented in the following manner: Principle results and findings are summarized immediately following this outline. Following the summary is a description of the experimental program including the experimental techniques employed and data analysis methods, characterization of the test explosive, and experimental results. The subsequent section addresses underlying physical mechanisms of shock compression and dynamic deformation uncovered by the new experimental results and a shock Hugoniot EOS model developed to describe the unreacting dynamic response of PBXW-128 explosive is presented. The final section discusses further testing and modeling needs required to address continued material response uncertainties and modeling weaknesses for PBXW-128 in particular, and plastic bonded explosives in general.

SUMMARY

Samples of PBXW-128 explosive were prepared by NSWC Indian Head Division, Yorktown detachment. Unreacting dynamic equation-of-state (EOS) and strength properties were measured through controlled gas gun impact experiments performed at the Explosive Components Facility of the Sandia National Laboratories.

The majority of tests were performed to determine the shock EOS properties of PBXW-128 using an established technique in which a disc of explosive undergoes normal and flat impact on a thin metal diagnostic plate. The acceleration history of the metal plate following impact is measured with velocity interferometry techniques and provides, through appropriate analysis, shock Hugoniot and decompression isentrope properties of the explosive. The technique is expected to be particularly appropriate at shock stress levels in explosives at which reaction buildup complicates other Hugoniot diagnostic methods.

Several additional impact tests were performed to access dynamic compression and spall strength properties of PBXW-128 explosive through time-resolved velocity wave profile measurements.

Shock Hugoniot properties measured within a pressure range over approximately 0.3-3 GPa exhibited strong nonlinear behavior in the shock-velocity-versus-particle-velocity (U vs. u) representation, but merge nicely with higher pressure data of Lindfors (1997).

Several possible physical mechanisms are suggested for the marked nonlinearity in the U vs. u shock Hugoniot data for PBXW-128 in the neighborhood of 0-3 GPa. One explanation relates to effective stress features occurring in the compression of a mixture of HMX molecular crystals and a polymer binder with markedly disparate compressibilities. Other explanations explore a possible glass transition in the binder within this dynamic compression range or a transformation within the HMX

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crystal. A small level of porosity may also play a role in the observed nonlinearity. There is insufficient data to rule out the any of the possible mechanisms.

The static crush data of Ebon and Chiarito (1986) on HMX explosive powders was explored because of the relevance of this crush strength data to the dynamic compression of HMX-binder mixtures. The crush strength versus compression of the powders demonstrated a strong compression nonlinearity qualitatively similar to the PBXW-128 U vs. u data. Quantitative assessment suggests that particle densities within the PBXW-128 mixture are too diluted to exhibit crush strength sufficient to explain the observed nonlinearity in the U vs. u shock data. Enhanced strength due to dynamic or particle size/shape effects could alter this conclusion, however.

A nonlinear analytic Hugoniot EOS has been developed which satisfactorily models the EOS data and extrapolates to the appropriate linear U vs. u behavior at higher shock pressures.

The shock data were examined for compressive shear strength behavior in the shock environment. With the possible exception of one compression and release hysterisis experiment no evidence for measurable dynamic shear strength in PBXW-128 within the range tested was observed.

Only a few spall strength measurements were made on the PBXW-128 explosive. These measurements indicated a dynamic tensile strength of approximately 15 MPa. Spall signatures, however, indicate complications of delayed tensile failure tentatively explained by initial cavitation at binder-crystal interfaces followed by extensive local stretching deformations. The current data are consistent with recent spall measurements of Kanel' *et al.* (1994) on polymer-filler systems.

EXPERIMENTAL PROGRAM

Within the present investigation shock equation-of-state (EOS) and dynamic-strength properties of unreacting PBXW-128 explosive were explored through controlled gun impact experiments. There currently exists a fairly mature technology for conducting and diagnosing such material testing experiments and assessing the desired material property data. It does not follow that such testing is routine. New materials and increasingly sophisticated material property requirements continue to challenge, and some times frustrate, the more conventional methods of the past.

The present test program was performed on the Sandia National Laboratories (Albuquerque) Explosive Components Facility single stage compressed gas gun. This launcher is capable of achieving velocities from a few 10's of meters per second to a maximum of approximately 1600 meters per second. Bore diameter of the launcher is 63.5 mm. Controlled planar impact (uniaxial strain) experiments were performed in all cases

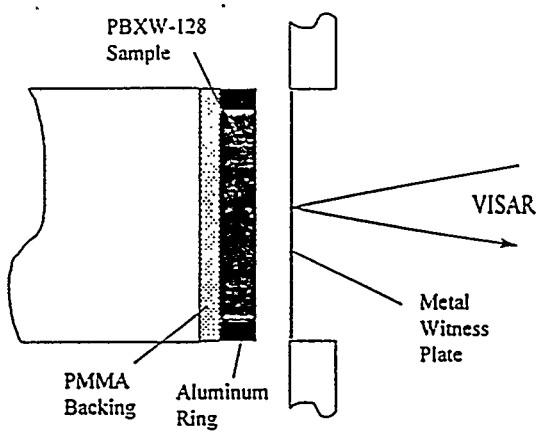

FIGURE 1. TEST CONFIGURATION

and velocity histories of motions imparted by the impact were measured with velocity interferometry (VISAR) techniques [Barker and Hollenbach, 1972]. Impact velocities were measured with electrical shorting pins to an accuracy of ±1%.

Two distinct test configurations were used in the investigation. The first, called the plate acceleration technique, concentrated on measurements of unreacted Hugoniot and release adiabat EOS properties of the explosive. The second transmission wave technique probed dynamic compressive strength and tensile (spall) strength properties.

Plate Acceleration Experiments

This technique is configured to measure Hugoniot and release adiabat EOS properties. The test configuration is shown in Figure 1. The explosive sample is mounted in the projectile as shown. A metal witness plate (copper or aluminum in the present study) is mounted in a stationary target assembly. The measured velocity histories (which are shown later) display the acceleration characteristics of the plate due to the impact-induced pressure from the explosive sample. The velocity history consists of a series of steps which tend to merge into a continuous acceleration curve late in the history. The characteristic time of each step corresponds to a stress-wave reverberation through the witness plate. The amplitude is determined by the current pressure at the explosive-plate interface.

Equation of state properties of the explosive sample are extracted from these velocity histories in the following manner: Each velocity step Δu_i is a consequence of a pressure p_i maintained at the interface between explosive sample and metal plate during the transit of the corresponding wave across and back through the plate. Momentum conservation for a steady wave then requires that,

$$p_i = \frac{1}{2}\rho c \Delta u_i \qquad (1)$$

where ρ and c are the density of the plate material and the wave speed, respectively. The factor of ½ comes about because the free surface velocity measurement provides a Δu_i which is twice the magnitude of the interior particle velocity. The first velocity step, $i = 1$, provides the Hugoniot pressure. Subsequent steps, $i > 1$, correspond to monotonically decreasing pressure levels on the decompression adiabat for the material.

Reasonable values for the wave speed for most metals can be estimated. This knowledge is not necessary, however, in that wave speeds for each reverberation can be determined from the data. Namely,

$$c = \frac{2h}{\Delta t_i} , \qquad (2)$$

where h is the plate thickness and Δt_i is the round trip transit time of the corresponding wavelet. Combining Equation 1 and 2 yields,

$$p_i = \rho h \frac{\Delta u_i}{\Delta t_i} , \qquad (3)$$

which is readily recognized as an incremental representation of Newton's law. In fact, Equation 3 can continue to be applied to the measured velocity history after discrete steps are no longer discernible.

The velocity at the interface relative to the state ahead of the shock wave propagating back into the explosive sample and corresponding to the current pressure p_i is given by,

$$u_{ri} = V_p - \frac{u_{i-1} + u_i}{2} . \qquad (4)$$

The measured set $\{ p_i, u_{ri} \}$ constitute points on the decompression adiabat of the test material from the shock Hugoniot state given by $p_h = p_1$ and $u_h = u_{r1}$.

Spall Strength Experiments

The technique used to measure the dynamic fracture strength of the material to transient tensile stress pulses (the spall strength) follows methods which have been used to test numerous other materials. A stationary disc of the explosive material to be tested is subjected to planar impact by a thinner disc of inert material (in this case the plastic polymethyl-methacrelate or PMMA). Impact of this plate induces a sharp compressive pulse in the test material which propagates through, reflects off of the opposite free surface, and carries the material into dynamic tension.

A VISAR is then used in the experiment to monitor the motion of the free surface during the wave propagation processes leading up to dynamic tensile failure. The recorded velocity history, if spall failure occurs, will exhibit a wave signature (frequently called the pullback signal) whose amplitude is proportional to the dynamic tensile strength of the material. To a reasonable approximation this spall strength can be shown to be given by [*e.g.*, Grady and Kipp, 1993]

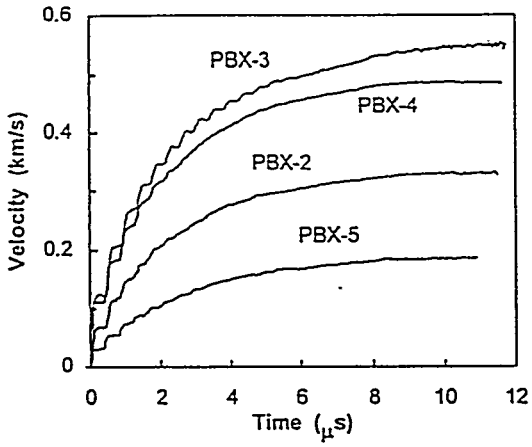

FIGURE 2. VELOCITY HISTORIES.

$$p_{sp} = \tfrac{1}{2} \rho c \Delta u_{pb} , \qquad (5)$$

where ρ and c are the density and wave speed in the test sample, respectively, and Δu_{pb} is the amplitude of the measured pullback signal.

MATERIAL CHARACTERIZATION

The present material is a plastic-bonded explosive (PBXW-128) consisting of a mixure of HMX and polymer binder. The polymer component represents a significant fraction of the material (23% by mass) in this explosive. The Class V-HMX is a moni-modal powder with characteristic size in the neighborhood of 8 μm [Anderson, 1997]. The HMX used is a molecular crystal stable in the β-HMX monoclinic structure at standard temperature and pressure [Elban and Chiarito, 1986]. Measured density and sound speed for the present PBXW-128 explosive are 1510 ±30 kg/m^3 and 1.68 ±0.05 km/s, respectively.

EXPERIMENTAL RESULTS

Hugoniot Data

In all of the plate acceleration tests, discs of explosive in excess of 10 mm in thickness and approximately 50 mm in diameter were bonded with epoxy into the face of a projectile, accelerated in a single stage gas gun and caused to undergo normal (planar) impact on discs of copper approximately 1 mm in thickness and 50 mm in diameter see Figure 1). Velocity histories were recorded at a central point on the back free surface of the copper or aluminum witness plate.

Velocity profiles for several representative plate acceleration tests are shown in Figures 2. Test parameters for the four profiles shown in Figure 2 are provided in Table I.

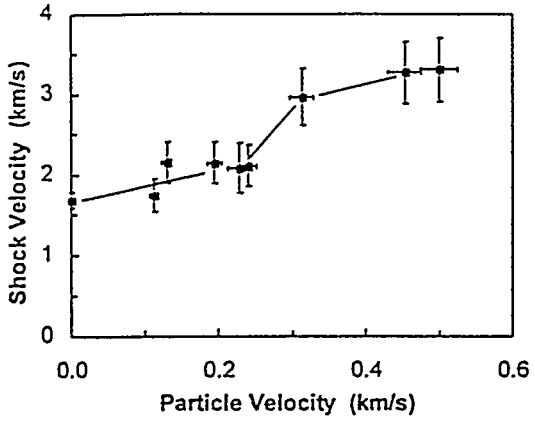

FIGURE 3. U vs. u HUGONIOT DATA.

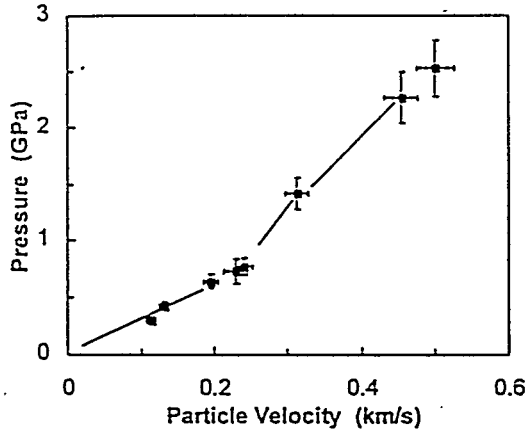

FIGURE 4. P vs. u HUGONIOT DATA.

Principal Hugoniot states are determined from the amplitude of the first step in the measured velocity history through the analysis methods discussed earlier. Hugoniot data are provided in Figures 3 and 4. Hugoniot properties are provided in Table 2. Shock velocity and Hugoniot strain are calculated through $U = p_h/\rho_o u_h$ and $\varepsilon_h = u_h/U$.

TABLE 1

TEST PARAMETERS

Test Number	Impact Velocity (m/s)	Explosive Plate (mm)	Witness Plate (mm)
PBX-02	347	12.87	1.013
PBX-03	557	12.83	1.006
PBX-04	509	12.84	1.016
PBX-05	211	12.91	1.013

The aluminum witness plates used for the lowest velocity data exhibited erratic VISAR velocity profiles which were not fully understood. Several tests attempted at particle velocities below 100 m/s exhibited negative velocity excursions and could not be analyzed.

Release Data

As discussed in the earlier description of the experimental methods the velocity history in the plate acceleration experiments after the first step is determined by the release or decompression properties of the test material. These release paths can be extracted from the acceleration data by the analysis described in an earlier section. Release paths from Hugoniot states in the present test series are shown in Figure 5.

In Figure 5, symbols with error bars identify Hugoniot states. Other symbols represent the discrete release states determined by the step-wise procedure described earlier.

The curves shown are quadratic fits to the discrete release states for each of the release paths.

There is some scatter in the release data. This scatter is likely a consequence of the nonplanarity of the test samples used in the present study. Test samples were less than satisfactory due to the way they were cast. However, despite the poor samples, to first order, release behavior is observed to lie on or near the compression Hugoniot for PBXW-128 indicating little equation-of-state hysteresis in the compression and decompression process.

A closer comparison of the Hugoniot and release data reveals some interesting observations, however. Release paths for the two highest pressure points (>2 GPa) lie below the approximately 1.5 GPa Hugoniot point. This observation can be questioned because of the uncertainty in the latter Hugoniot point but the scatter bars shown are conservative and indications were that this was a particularly good test. Yet if this were true then the Hugoniot and release data would appear to indicate some hysteresis on the order of 0.1-0.2 GPa.

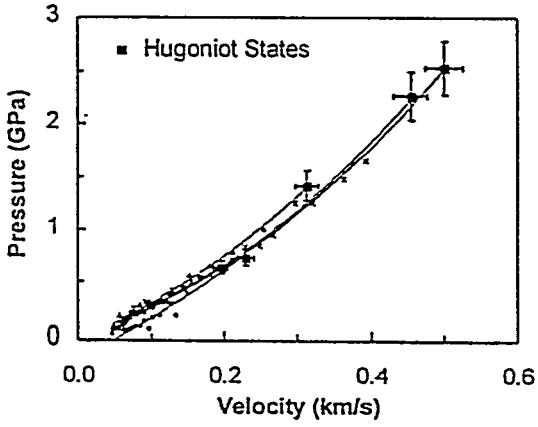

FIGURE 5. RELEASE PATH DATA.

Spall Data

Tests PBX-6 and PBX-10 were the two spall esperiments performed. The free surface velocity profile for test PBX-10 is shown in Figure 6. The higher level experiment (PBX-06) was complicated by electronic noise due to laser operation difficulties. The lower level experiment is comparable in character to similar spall tests performed by Kanel' *et al.* (1994) on filled and unfilled polymeric materials.

There are several features in the spall profiles unique to the constitutive response of the present explosive-binder system. First, note that the compressive wave first emerging at the recording surface is a single sharp (discontinuous) shock wave. There is no elastic precursor wave often seen in solid materials and indicative of a dynamic yield strength. Also there is no structuring (spreading) of the compressive wave characteristic of the wave dispersion influences of certain strain rate or hardening mechanisms.

Second, velocity relaxation, or reduction, immediately behind the peak of the compressive shock suggests overtake of the unloading wave created by step loading of the sample through impact of the finite-thickness PMMA plate. The hesitation in the velocity history approximately 0.5 μs after the shock peak is believed to identify the peak tension in the test material before spall failure initiates. This interpretation is consistent with similar results and interpretations of Kanel' et al. (1994).

There is not a subsequent reversal in the sign of the acceleration after spall initiates, as is typical in many other condensed substances. This behavior appears to be a feature unique to these rubber-like materials.

TABLE 2

HUGONIOT PROPERTIES

Test No.	Particle Velocity (m/s)	Hugoniot Stress (GPa)	Shock Velocity (km/s)	Hugoniot Strain
01	229	0.73	2.08	0.110
02	313	1.42	2.97	0.106
03	500	2.53	3.31	0.151
04	454	2.27	3.27	0.139
05	195	0.64	2.15	0.091
07*	131	0.43	2.15	0.061
11*	113	0.30	1.74	0.065
12	241	0.77	2.11	0.114
* Aluminum witness plates (others were copper).				

The current explanation is that following incipient cavitation at the maximum tensile stress, the ability of the rubber-like material to accommodate large local strains precludes immediate detachment of the spall plate. Thus, continued deceleration occurs due to the relaxing but still nonzero tensile stress at the spall plane. Although an intuitively reasonable explanation, there is clearly need for further studies on the nature of spall in polymers and polymer-filler systems.

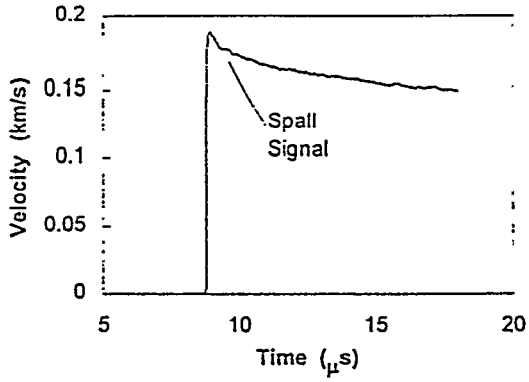

FIGURE 6. TEST PBX-10 SPALL PROFILE.

Based principally on the results of test PBX-10 we currently report a spall strength for PBXW-128 of approximately 15 MPa.

INTERPRETATION AND MODELING OF EOS DATA.

The key equation-of-state characteristics uncovered in this investigation is the nonlinearity reflected in the U vs. u data below shock amplitudes in the neighborhood of 2.0 GPa. On the following pages we assess underlying deformation and/or compression mechanisms responsible for the measured behavior and propose computationally amenable models to describe the response.

Mechanisms

Materials in which nonlinear compression is controlled by a single mechanism are commonly found to be reasonably well described through a Hugoniot response governed by a linear U vs. u behavior,

$$U = C_o + Su \ . \qquad (6)$$

Changes in the mechanisms controlling compression will lead to deviations in linear U vs. u behavior. For example, a change of phase, leading to a reconfiguration of the lattice structure and the corresponding intermolecular potential, will lead to nonlinearity. Similarly, in the shock compression of a porous solid in which compression within the lower range is dominated by void collapse while higher pressure compressions are controlled by lattice elasticity, such nonlinearity is also observed. Frequently such transitions can lead to a bilinear U vs. u behavior.

There are two possible physical mechanisms underlying the nonlinear U vs. u characteristic of PBXW-128 explosive within the Hugoniot pressure range below

about 2 GPa. One explanation is suggested by the behavior of porous solids during shock compression in which crushing of the pore volume occurs. The second relates to compression characteristics of polymeric materials due to the rubber-to-glass transition.

Quite large values for the slope of the U vs. u relation (S ~ 4-5) are observed for porous solids within the range of compressive crushing. The present explosive-crystal-elastomer-binder mixture is not a porous material. There are, however, dramatic differences in the compliances of the polymer binder [Gupta, 1992] and the HMX crystal [Sheffield *et al.*, 1995].

Deformation incompatibility brought about by this large difference in compliance can lead to deformation-induced fracture (crushing) of the stiffer explosive crystal skeleton of the mixture. As in the case of a fully porous material, this crushing compression mechanism will contribute to the U vs. u EOS characteristics which differ uniquely from that due strictly to lattice compressibility.

The present U vs. u data for PBXW-128 explosive are shown in Figure 3. Accounting for both the ultrasonic compliance and the high pressure trend, a trilinear representation captures the salient features of the data. Within the context of a crushing mechanism explanation of nonlinear behavior, the modest slope lower amplitude region corresponds to compression governed principally by the polymer binder as HMX crystal filler begins to make contact and lock up. A small degree of porosity also probably contributes to the behavior in this region. The second region of steep slope identifies the regime in which large compliance differences in matrix explosive and binder lead to compressive crushing of the HMX crystal matrix. The third region is a transition to the higher strain equilibrium mixture compressibilities as discussed by Bernecker (1996) and measured by Lindfors (1997) in which a slope of S = 1.45 is consistent with compressions governed strictly by intermolecular forces.

A crush mechanism explanation of the explosive matrix is supported in part by recent Hopkinson bar data on PBXW-128 [*e.g.*, Tasker *et al.*, 1997]. These data have shown a bilinear stress vs. strain compression behavior suggesting that early compression is rubber-like until sufficient volume strain has occurred to bring HMX crystals into contact. Substantial stiffening is observed in the later portion of the Hopkinson bar compression stress vs. strain curve indicating an increasing role of the HMX matrix in the compressibility. Although Poisson's ratio for this material is not known, estimates of the volume strain occurring in the Hopkinson bar experiments at which the transition to stiffer behavior occurs is not inconsistent with the approximately 10% volume strain achieved in the Hugoniot experiments at which transition to a steeper slope in Figure 3 is observed.

An explanation for the observed EOS nonlinearities for PBXW-128 through a matrix crush mechanism can be explored further by examining static and dynamic compression data on HMX powders. Static compression data on HMX have been provided by Elban and Chiarito (1986). In their study sieve-cut HMX powders of initially 56-58% of theoretical mass density (TMD) are compacted to specified levels. For comparison, corresponding dynamic (shock) data on porous HMX have been provided by Scheffield *et al.* (1995). The static data can be fit to a power law curve of the form,

$$p_c = a\left(V_o/V\right)^n , \qquad (7)$$

where $\alpha = V/V_o$ and V_o is the crystal density specific volume of HMX (reciprocal of the TMD) while $a = 382$ MPa and $n = 16.6$. Using the relations for the pressure derivative of the bulk modulus $K' = d\ln p_c / d\ln V$ and $K' = 4S - 1$ results in a shock nonlinearity parameter of $S = 4.4$. Such a value for S is in reasonable accord with the rapidly rising portion of the U vs. u data shown in Figure 3. The dynamic crush data of Sheffield *et al.* (1995) exhibits excessive scatter but lies about a factor of two to three higher than the static data.

On the other hand, a quantitative examination of the static crush data of [Elban and Chiarito, 1986] is less convincing in supporting a matrix-crush mechanism governing the EOS nonlinearities in PBXW-128 explosive. The powdered (porous) HMX at void volumes consistent with the volume fractions of binder and explosive in PBXW-128 only supports crushing pressures of approximately 1-10 MPa. This level of matrix pressure would be insufficient to account for the observed trends in the PBXW-128 data. However, dynamic effects (such as is suggested by the data of Sheffield *et al.*, 1995) or strength differences due to differences in matrix configuration (size, shape) could account for the discrepancy.

The further possible physical explanation for the observed nonlinear behavior of PBXW-128 is due to nonlinearities in the compression EOS properties of the binder polymer. Initial compliance of elastomeric materials are governed in part by a free volume component to the total specific volume of the material [*e.g.*, Moonan and Tschoegl, 1985]. Much like a porous material, this free volume is substantially more compliant than that of the associated lattice. It can contribute significantly to the EOS compressibility until a glass transition [*e.g.*, Turnbull and Cohen, 1961] is achieved at a characteristic transition pressure associated with pressure-induced collapse of the polymer free volume. A glass transition during shock compression of the binder polymer could account for the observed nonlinearity.

At present both matrix crush mechanisms and polymer glass-transition EOS properties must be considered as possible causes for EOS nonlinearities in PXW-128 explosive. Neither the present data nor earlier data are sufficient to support one mechanism over another.

Equation of State Modeling

Nonlinearities in U vs. u behavior not unlike that emerging in the present work have been observed as a general behavior in liquids [*e.g.*, Voskoboinikov, *et al*, 1967]. To address this material behavior a shock-velocity-versus-particle-velocity EOS representation was developed by Woolfolk *et al.* (1973) of the form,

$$U = C_o + Su - ae^{-bu} \quad . \qquad (8)$$

Liquids constitute a material state in which a molecular free volume plays a role in the lower pressure compressibility. Consequently, the form of Equation 8 is reasonable, where the limiting linear U vs. u behavior characterizes molecular compressibilities whereas the additional term accounts for softening of the EOS curve brought about by free volume influences. Bernecker (1996) has suggested that the form of Equation 8 may be appropriate for the EOS response of polymer binders and binder systems.

A nonlinear EOS relation between the shock velocity U and the particle velocity u is inconvenient to the structure of some of the key computational codes. Following the semi-empirical nature of Equation 8 it is possible, however, to formulate a functional form separating the limiting linear behavior and the low pressure nonlinear behavior which is more compatible with computational implementation.

An analytic Hugoniot EOS relation dependent explicitly on the Hugoniot strain ε of the form,

$$U = \frac{C_o}{1 - S\varepsilon} - be^{-(\varepsilon\ \varepsilon^*)^n} \quad , \qquad (9)$$

was selected to represent the present data.

The parameters in Equation 9 can be reasonably interpreted in terms of the compression physics leading to the earlier trilinear idealization of the data. The limiting high pressure, linear behavior is of course, characterized by C_o and S.

The difference between C_o and the softened intercept determined by the zero pressure bulk compressibility of the mixture is described by the parameter b. The remaining parameters ε^* and n describe lockup and crush characteristics of the HMX explosive matrix.

TABLE 3

HUGONIOT EOS PARAMETERS

C_o (km/s)	S .	b (km/s)	ε^*	n
2.62	1.5	1.02	0.11	10

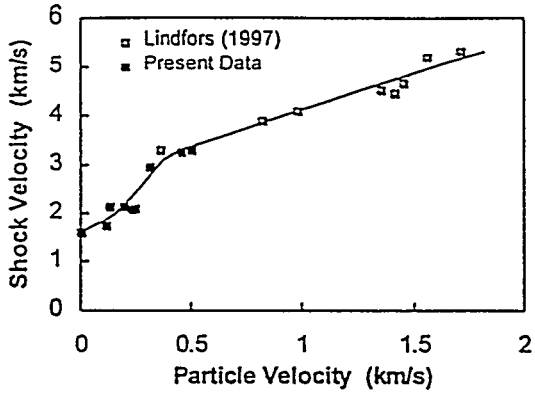

FIGURE 7. PBXW-128 SHOCK DATA AND ANALYTIC MODEL (EQ. 9).

These later parameters can be expected to depend on details of the matrix particulate including size statistics, degree of dilution and strength. EOS parameters for a statistical fit to the experimental data for PBXW-128 are provided in Table 3. This functional fit is compared with the data in Figure 7. As can be seen the agreement is excellent.

CLOSURE

New shock data on the Navy PBXW-128 explosive uncovered unexpected equation of state and/or high-strain-rate deformation complexities within 0-3 GPa pressure range in this explosive. Shock Hugoniot experimentation using the plate acceleration technique was found to be particularly appropriate for the present explosive material. The present test method should be considered in particular when unreacting Hugoniot states are desired for explosives in which concern about reaction buildup is present.

The new data and observed complexities opened questions concerning the underlying compression and/or deformation mechanisms responsible. Two likely explanations relating to deformation complexities brought about by polymer-explosive mixtures and to possible free-volume, glass-transition anomalies in the polymer binder were explored. Existing dynamic data on PBXW-128 and on its component explosive and binder materials were insufficient to reject either of the possible mechanisms.

Further shock EOS studies should be considered on the binder material alone. Such testing should target possible free-volume and glass-transition EOS features within the expected pressure range identified in the present test series on PBXW-128 explosive.

An experimental and modeling effort addressing the dynamic deformation and shear strength complications of PBXW-128 in the unreacting lower stress range (0-3

GPa) should also be considered. The effects of mixing materials with disparate strengths and compressibilities are largely unknown. The importance of this mechanism to the dynamic response of PBXW-128 explosive in lieu of its large binder content has not been conclusively demonstrated. This constitutive feature will be clearly relevant to the preponderance of plastic-bonded explosive in which higher fractions of explosive are present.

The present study has also demonstrated how static and dynamic compression testing on porous explosives can provide material property data and model parameters for the corresponding explosive-binder mixtures. Such testing with these objectives in mind should be considered.

The small amount of dynamic tensile (spall) strength data generated in the present work and other data generated by earlier workers have revealed mechanism complications not experienced in more thoroughly investigated solids. Some careful thought and new techniques will be necessary before material models and relevant strength data adequate to simulation of failure dynamics in plastic-bonded explosives will be available.

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.