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PBXN-110 Burn Rate Estimate

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It is estimated that PBXN-110 will burn laminarly with a burn function of B = (0.6-1.3)*$P^{1.0}$ (B is the burn rate in mm/s and P is pressure in MPa). The following is a brief discussion of how this burn behavior was estimated.

Laminar vs. Convective?

In predicting the deflagration rate of an energetic material one must first determine whether the material is likely to burn laminarly or convectively. Laminar burns appear linear and reproducible (see figure 1, PBXN-9 data- see Table 1 for material constituents); in contrast, convective burns will be much faster (orders of magnitude) and erratic (see figure 2, LX-07 data). Ultimately convective burning results from deconsolidation of the material allowing the flame to travel rapidly through the material via cracks and pores. The binder type and amount play a major role in the burn type (laminar vs. convective) because both parameters affect the materials mechanical properties. A large wt % of binder and a binder that renders the explosive more malleable and putty-like tend to result in laminar burning. Insufficient binder and very stiff binders tend to result in convective burns. PBXN-110 has both a large wt % binder and is very malleable due to the soft poly-butadiene binder, therefore, I expect PBXN-110 to burn laminarly over a wide pressure range.

Burn Rate

The laminar burn rate of a material depends on the binder type, explosive type and particle size. Unfortunately the burn rate is considerably harder to predict with confidence but an educated guess can be made. Figure 1 shows the burn rate behavior for LX-04 and RX-04-AN (fits only- no raw data). The only difference between these two materials is the particle size distribution: the average particle diameter for RX-04-AN is 2.5 times larger than for LX-04 (average particle diameters were calculated using equation 1 and reported in Table 1). The RX-04-AN generally burns slower than LX-04, as expected for the larger particles. PBXN-9 average particle diameter is 2.1 times larger than LX-04, however, PBXN-9 burns slightly faster than LX-04 indicating that binder plays an important role in the burn rate.

$$T = \Phi_p d_e \rho_e / 6\rho_p \qquad (1)$$

T is the coating thickness, Φ_p is the weight fraction of binder/plasticizer, d_e is the mean HMX particle diameter and ρ with the subscript 'e' and 'p' are the densities of the explosive and binder/plasticizer respectively. The mean particle diameter was estimated by taking the weighted average of each sieve size group; for example, all the particles that pass through the 44 μm sieve were assumed to have a diameter of 44 μm. This method uniformly overestimates the particle diameters for all the materials. For PBXN-9 and PBX-110 the density of the binder/plasticizer was a weighted average of the constituent binder and plasticizer.

The burn rate is modeled using equation 2:

$$B = aP^n \quad (2)$$

where B is the burn rate (mm/s), a is the burn rate coefficient (mm/s·MPa^n), P is the pressure (MPa) and n is the pressure exponent (dimensionless). In general, HMX materials all tend to have the same pressure exponent (n) of 1.0, therefore, I would expect PBXN-110 to also have a pressure exponent of 1.0.

Estimating the burn rate coefficient is much more difficult. Because the binder in PBXN-110 and PBXN-9 are similar (both have a polybutadiene binder and are halogen free), it is reasonable to expect PBXN-110 to have a burn rate coefficient (a) similar to that of PBXN-9. However, the substantial increase in particle diameter for PBXN-110 relative to PBXN-9 will most likely slow the burn rate. A crude method for estimating the burn coefficient is to set up a ratio of the burn coefficient with the inverse average particle diameter for PBXN-9 and use that ratio to calculate the burn coefficient given the particle diameter for PBXN-110 as shown in equation 3:

$$\frac{a_{PBXN9}}{1/d_{PXBN9}} = \frac{a_{PBXN110}}{1/d_{PXBN110}} \quad (3)$$

Where 'd' corresponds to the average HMX particle diameter and 'a' corresponds to the burn rate coefficient. According to this ratio, the burn rate coefficient for PBXN-110 is 0.6. The same calculation was done with LX-04 in order to predict the burn rate for RX-04-AN and yielded an answer (a = 0.4) that is smaller than the measured value (a = 0.64). Thus this method only provides an estimate and PBXN-110 may have a very different burn coefficient with a likely range of 1.3-0.6.

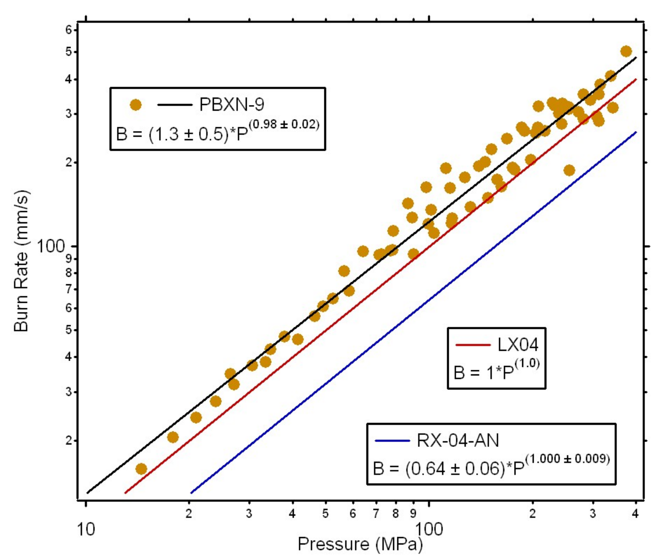

Figure 1. Burn behavior of PBXN-9 (orange dots/black line), LX-04 (Red line) and RX-04-AN (blue line).

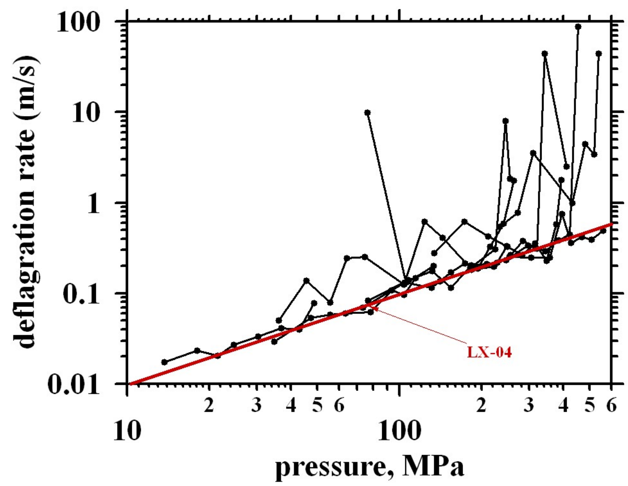

Figure 2. Burn behavior of LX-07 (black dots/lines) showing a erratic and rapid burn rate.

Table 1. Materials and relevant parameters.

Name	Average Particle Diameter (μm)	Binder Coating Thickness (μm)	Wt % HMX	Binder	Wt % Binder
PBXN-9	144	3.78	92	DOA	6
				Hytemp 4454	2
PBXN-110	317	13.71	88	HtPB	5.378
				IDP	5.378
				other	1.244
LX-04	68	1.76	85	Viton	15
RX-04-AN	171	4.40	85	Viton	15
LX-07	68	1.19	90	Viton	10