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Detonation Performance Measurements of Cyclotol 80/20

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Abstract. Cyclotol is a melt-castable high explosive composed of RDX and TNT, and typically a small amount of HMX. The term Cyclotol may apply to other mixtures of these components, but for the present work, experiments were conducted using Cyclotol containing 80 wt% RDX and HMX and 20 wt% TNT (we will refer to mixtures of RDX and TNT using the notation RDX%/TNT%). In the current effort, we report detonation velocity measurements at several diameters for unconfined rate sticks. The results are compared to prior diameter-effect data for Cyclotol 77/23, and a density-corrected Eyring-form fit for all available rate-stick data is reported.

INTRODUCTION

Explosives composed of mixtures of RDX and TNT, and typically a small amount of HMX, are generally referred to as cyclotols in the United States. A mixture nominally composed of 60 wt% RDX and 40 wt% TNT (60/40), referred to as Comp B, has been in widespread use in explosive munitions, due at least in part to the ability to form charges by casting. Mixtures with increased percentages of RDX have been developed to achieve higher performance. Increasing the amount of RDX in the mixture, however, comes with the drawback of increased solids at casting temperatures, which makes production of high quality castings more difficult. Mixtures of 70/30 and 75/25 have been used where the higher performance is needed, while still maintaining the ability to be melt-cast. In 1976, Campbell and Engelke [1] presented a new fitting form for diameter effect in heterogeneous explosives, and reported fitting parameters for Cyclotol 77/23. Their results are based on nine rate-stick experiments, conducted with diameters ranging from 5.6 mm to 101.6 mm diameter and documented in Gibbs and Popolato[2].

In the present effort, we investigated Cyclotol 80/20 using parts machined from a single billet. A sample of this billet was analyzed using High Pressure Liquid Chromatography/Mass Spectrometry (HPLC/MS), and found to contain 79.2 wt% RDX and HMX and 20.8 wt% TNT. This result suggests the billet was formulated as Cyclotol 80/20. We conducted three unconfined rate-stick experiments with this explosive and measured front curvature in addition to detonation velocity. In this work, results are presented as detonation velocity measurements as a function of rate stick diameter. The results are compared to the prior Cyclotol 77/23 data and a density-corrected Eyring-form fit to the combined set of data is reported.

EXPERIMENTAL CONFIGURATION

The dimensions and densities of each rate-stick are provided in Table 1. All three unconfined rate-sticks were assembled by joining machined 38.1 mm long right-circular cylinders of Cyclotol using a minimal amount of Devcon 5 minute epoxy between pellets. The epoxy was allowed to cure while the rate stick was held in machined v-blocks to ensure accurate alignment.

To measure detonation velocity, the rate sticks were fitted with eleven ionization wires placed in a line along the length of the charge. The wire positions were measured to within ± 5 μm using an optical comparator. To measure the profile of the detonation front with a streak camera, a 6.35-mm-thick PMMA window was placed on the end of the charge. The windows were vapor coated with aluminum to act as a mirror for the streak camera. The measured detonation front profiles will be reported in a subsequent publication. A complete rate-stick assembly is shown in

Fig. 1. Visible in the figure are the ionization wires along the top of the rate-stick, and the streak camera window in the upper-right corner of the image.

TABLE 1. Measured dimensions, densities, and detonation velocities of Cyclotol 80/20 rate sticks.

Charge Diameter mm	Length mm	Density g/cc	Detonation Velocity (mm/μs)	Standard Error (mm/μs)
7.47	228	1.753	8.101	0.0025
20.0	305	1.752	8.223	0.0047
25.4	305	1.751	8.255	0.0037

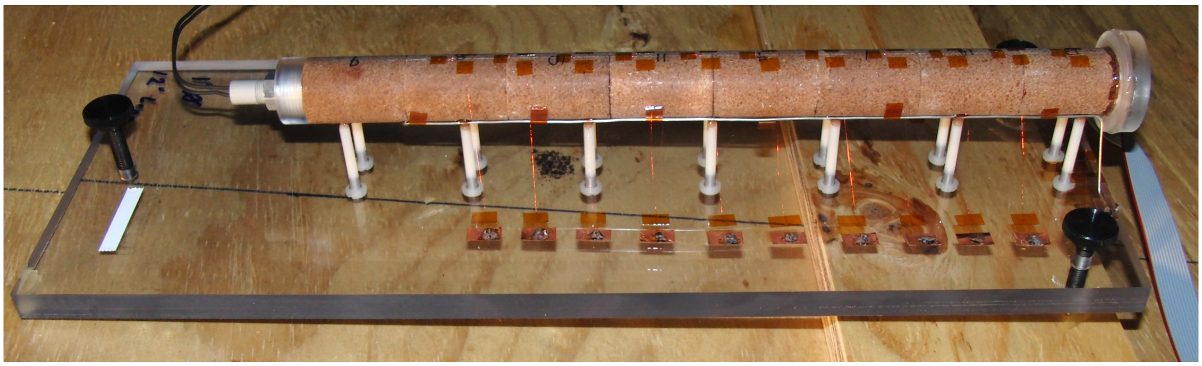

FIGURE 1. Photograph of the 25.4-mm-diameter Cyclotol rate stick.

RESULTS AND ANALYSIS

Detonation velocities for the Cyclotol rate sticks are summarized in Table 1. The velocities were computed as the slope associated with a line fitted to the position-time data for the ionization wires using the method of least squares. The standard error associated with the linear fit is also provided in the table. The low standard error values indicate a steady detonation velocity and accurate measurement of wire position and detonation time-of-arrival. The postion-time data shown in Fig. 2 was measured for the 7.47-mm-diameter rate stick; results for the other rate sticks are similar.

The detonation velocities reported in Table 1 are displayed in Fig. 3 where past results from Gibbs and Popolato [2] are also shown. The past results were measured using Cyclotol 77/23 with a density of 1.740 g/cc.

For many condensed phase explosives, the short Eyring form,

$$D_0 = D_{CJ}\left(1 - \frac{A}{R - R_c}\right), \tag{1}$$

can provide a good fit to experimental data, where D_0 is the measured detonation velocity, R is the charge diameter, and D_{CJ}, R_c and A are determined in the fitting process [1]. D_{CJ} represents the Chapman-Jouguet detonation velocity, while R_c represents the critical diameter and has units of length. The parameter A also has units of length.

Because the available Cyclotol 80/20 and 77/23 detonation velocity data was measured at different initial densities, the fitting form below with an additional density correction term was used:

$$D_0 = D_{CJ}\left(1 - \frac{A}{R - R_c}\right)\left(1 + \alpha\left(\rho_0/\rho_n - 1\right)\right). \tag{2}$$

In this form, the multiplier $1+\alpha\left(\rho_0/\rho_n - 1\right)$ alters the detonation velocity, D_0, based on the parameters ρ_n, the nominal density, ρ_0, the measured density of each experiment, and α, a dimensionless density correction factor determined in the fitting process.

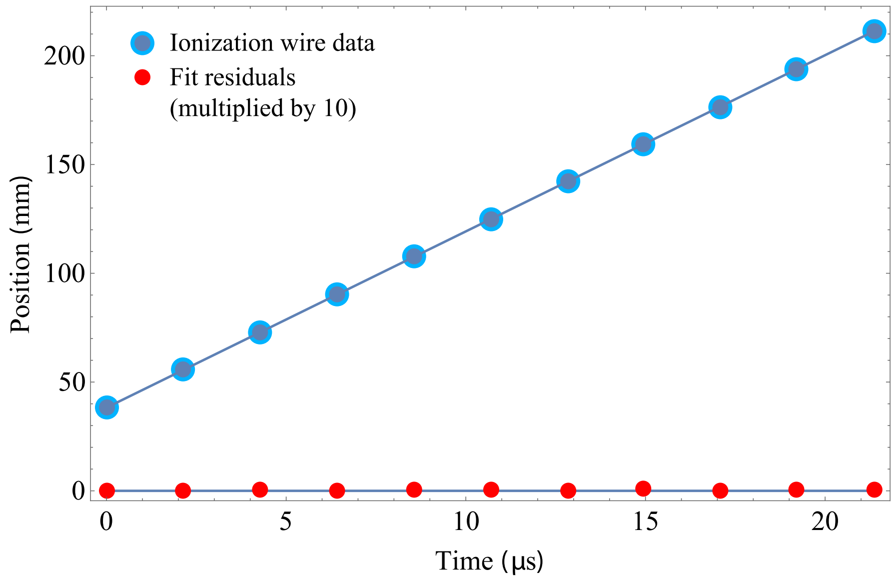

FIGURE 2. Ionization wire results for the 7.47 mm diameter rate stick.

The fitting parameters D_{CJ}, R_c, A, and α were determined using the method of least squares applied to the current Cyclotol 80/20 results and the prior 77/23 results. The computed parameters are provided in Table 2. Using these parameters and equation (2), the density-corrected detonation velocities for the current rate-stick experiments were computed and plotted in Fig. 3. The corrected velocities are 7.976, 8.109, and 8.139 mm/μs for the 7.47, 20.0, and 25.4 mm rate sticks, respectively. The density-corrected 80/20 data compares well with the prior 77/23 data in diameter-effect space. However, by applying the fitting form of equation (2) to the 80/20 and 77/23 data, we are assuming that the velocity differences observed are entirely due to either shot diameter or differences in density. The relative amounts of RDX and TNT in the Cyclotol also has an effect on detonation velocity, with higher detonation velocities observed for cyclotols with higher RDX content.

TABLE 2. Fitting parameters determined for the density-corrected Eyring form for Cyclotol 80/20 and 77/23.

D_{CJ} (mm/μs)	A mm	R_c mm	α -	ρ_n g/cm^3
8.187	0.06985	5.303	2.132	1.740

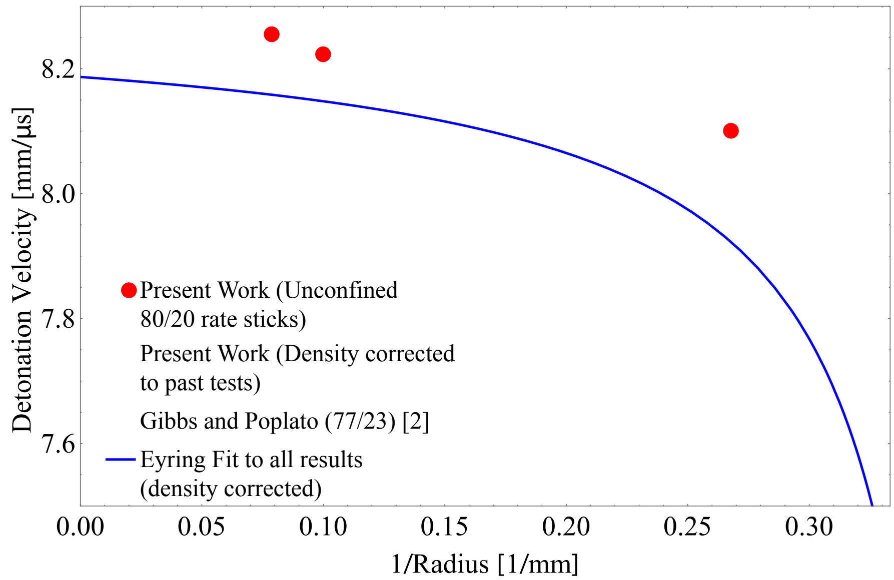

FIGURE 3. Diameter effect data for Cyclotol 80/20 and 77/23.

SUMMARY AND CONCLUSIONS

Three rate-stick experiments were fielded to measure the diameter-effect for Cyclotol 80/20. Compared to prior experiments conducted with Cyclotol 77/23, current results displayed higher detonation velocities, likely due to the higher density of the tested samples, and possibly the higher RDX content as well. A modified Eyring form with a density correction term was fitted to the Cyclotol 80/20 and 77/23 results. With the density correction applied, the detonation velocities measured for Cyclotol 80/20 were consistent with the past results measure for Cyclotol 77/23.

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