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ABSTRACT

Trinitrotoluene, RDX, and their 50/50 mixture were investigated at grain densities of 1.58, 1.70, and 1.68 g/cm^3, respectively. The detonation velocity, D, increased with increasing grain size. Changing the grain size from 2 to 10 mm increased D by 700 m/sec for TNT, and by 800 to 900 m/sec for RDX and the 50/50 mixture. For 10-mm grains, D was only 150 to 200 m/sec less than the maximum possible with the given grain density. The grain size permitting near-maximum D was expected to be proportional to the critical charge diameter, but experiment disproved this assumption. Maximum D for all explosives was reached at 10-mm grain size, while the critical charge diameter was 2 mm for TNT, 0.5 mm for RDX, and 3 mm for their 50/50 mixture.

The detonation properties of coarse-grained explosives are of practical interest because their detonation rate is far faster than that of fine-grained explosives at the same initial charge density, ρ_0.[1-4] Friederich[1] noted that the detonation rate of PETN charges ($\rho \approx 0.75$ g/cm^3) consisting of pressed 5-mm particles is 7.7 km/sec, while that of a finely divided powder is 4.7 km/sec. Analogous tests with large crystals of PETN showed only a small (~ 500 m/sec) increase in the detonation rate for a particle size, ℓ, of 9.5 mm. For 5-mm crystals, the detonation rate corresponds to the charge density. It is natural to assume that in coarse-grained charges in which the grain size exceeds the critical diameter of the explosive at the grain density, the detonation wave is propagated not by a continuous front, but through the individual grains.[5,6] Thus, the detonation rate must be compared not with the charge density, which is usually fairly low (0.7 to 0.9 g/cm^3), but with the grain density.[5]

Bulk-density charges of TNT and RDX and a cast 50/50-TNT/RDX mixture were studied to determine the dependence of the detonation rate and detonation impulse on the particle size. In some cases explosive or nonexplosive fillers were used in the voids, in other cases, not. The tests were made using 40-mm-diam, thin-walled glass tubes; increasing the tube diameter did not increase the detonation rate. Detonation was initiated by a detonation lens. The grain densities of the TNT, RDX, and 50/50-TNT/RDX mixture were 1.58, 1.70, and 1.68 g/cm^3, respectively. Grains smaller than 10 mm were obtained by grinding homogeneous pressed TNT and RDX or cast 50/50-TNT/RDX charges. The 10-, 15-, and 20-mm grains were cylindrical pellets whose height equaled their diameter. Because the volume fraction occupied by the grains decreased as their size increased, the charge density also decreased with increased grain size (Fig. 1). The detonation rate was studied using a streak camera. The precision of measurement was ± 200 m/sec.

The results, shown in Fig. 2, indicate that the detonation rate of all the explosives increases with increasing grain size. Increasing the grain size from 2 to 10 mm increases the detonation rate by 700 m/sec in TNT charges and by 800 to 900 m/sec in RDX and 50/50-TNT/RDX charges. For 10-mm grains,

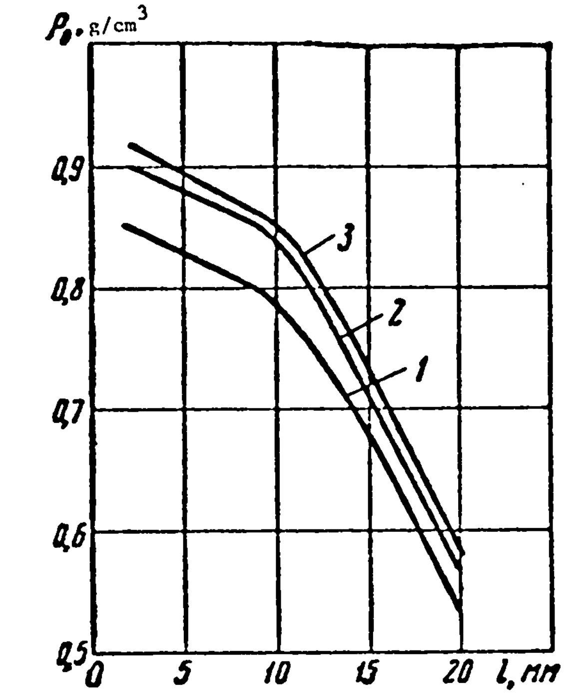

Fig. 1. Dependence of charge density (without water) on particle size. Charge diameter, 40 mm. 1. TNT, 2. 50/50-TNT/RDX, 3. RDX.

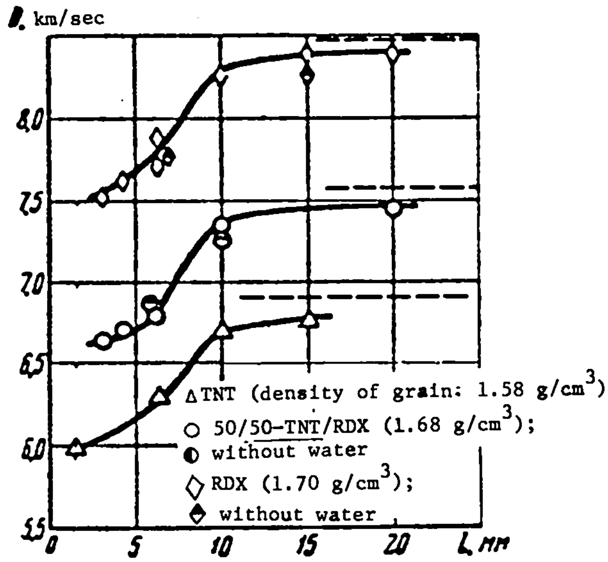

Fig. 2. Dependence of detonation rate of coarse-grained charges on the grain size.

the detonation rate is only 150 to 200 m/sec less than the maximum possible values, which correspond to the grain densities (broken lines in Fig. 2), and hardly changes with further increase in grain size. Because the detonation wave can be propagated through the individual grains only when their size exceeds the critical diameter of the explosive, d_{crit}, at the grain density, it is logical to expect that the particle size for which the detonation rate differs insignificantly from its maximum value will be proportional to d_{crit}.

Our results show that regardless of the detonation capacity of the individual explosives, as determined by their critical diameters (~3 mm for cast 50/50-TNT/RDX, ~2 mm for TNT, and ~0.5 mm for RDX), the maximum possible detonation rate is attained for one definite grain size, 10 mm, which exceeds the critical diameters of the explosives studied by a factor of 5 to 15. If losses during transfer of the detonation from grain to grain are neglected, it is possible to verify that when the grain size exceeds the critical diameter of the explosive the shortest path through the grains is essentially the charge length, and the detonation rate hardly differs from a value corresponding to the grain density.

Decreasing detonation rate with decreasing grain size can be caused by greater losses from the reaction zone in the grain itself, and by increased delay time during detonation transfer due to small contact surfaces and unavoidable buildup regions inside each grain.

To examine the effect of detonation in the grain itself on the total detonation rate of coarse-grained charges, we measured the detonation rate of RDX (ρ_0 = 1.69 g/cm^3) and of TNT (ρ_0 = 1.62 g/cm^3) as a function of the charge diameter. Figure 3 shows that in the 3- to 10-mm-diam interval the RDX detonation rate does not change, while that of TNT increases by only 300 to 350 m/sec. Thus, we were not able to explain completely the characteristic detonation traits of coarse-grained charges. The main factors determining the reduction in detonation rate should logically be the losses due to the poor grain contact and the buildup time of the wave during transfer from grain to grain.

The detonation rates of coarse-grained TNT and RDX charges with explosive and inert fillers are given in Table I. The table shows that with increased grain size, the detonation velocity of TNT and RDX does not depend on the filler. If the pressed pellets of TNT are replaced with cast pellets of the same 10-mm diam, the velocity decreases by 550 m/sec and hardly differs from that of TNT with a

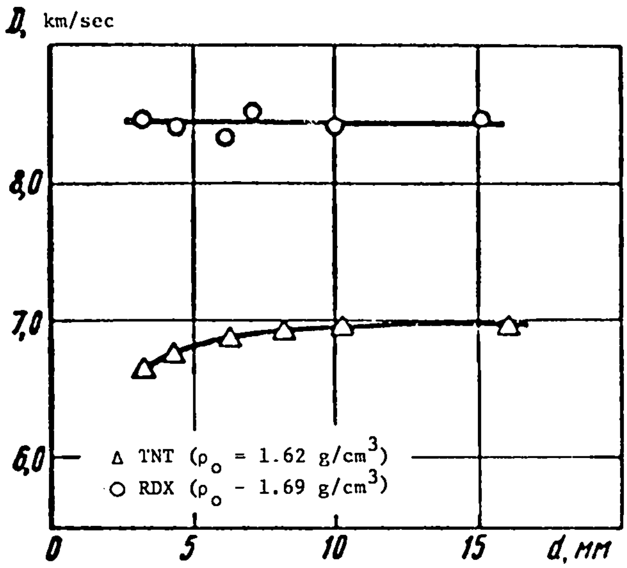

Fig. 3. Dependence of detonation rate on charge diameter.

particle size of 1.6 to 2.5 mm. This is related to the fact that the critical diameter of cast TNT exceeds the grain size, and the detonation wave cannot propagate through the grains.

One explosive property that characterizes the effect in the immediate vicinity of the charge is the relative detonation impulse. Other conditions, such as charge diameter and density, being equal, the relative detonation impulse is proportional to the detonation rate.[7] This is true for a normal detonation wave with a continuous front but does not take into account the physical structure of the charge. In this connection, it is interesting to compare the relative detonation impulses of charges of coarse-grained and fine-grained explosives of the same density.

The relative detonation impulses (Table II) were calculated from experimental data obtained with a copper crusher gauge similar to the Kast brisance gauge, using the dependence of the relative brisance, B, on the crusher gauge reading.[8] The 50/50-TNT/RDX mixture (ρ_0 = 1.68 g/cm^3), whose relative detonation impulse was taken to be 100%, was chosen as a standard.

Although the detonation velocities of coarse-grained charges of RDX and of the cast 50/50-TNT/RDX mixture are almost 3000 m/sec faster than

TABLE I.

Explosive	Grain size, mm	Filler	Charge Density, g/cm^3	Detonation Rate, km/sec
RDX	2.5-3.5	Water	1.38	7.50
	-	TNM*/hexane 82/18	1.51	7.90
	10	Water	1.35	8.25
		TNM/hexane 82/18	1.48	8.10
	15	-	0.73	8.20
		Water	1.31	8.30
		TNM/hexane 82/18	1.48	8.20
TNT	1.6-2.5	Water	1.32	6.00
			1.29	6.70
	10	Nitromethane	1.36	6.80
	10 (cast)	Water	1.30	6.15

*TNM-tetranitromethane

TABLE II.

Explosive	Grain size, mm	Filler	Charge Density, g/cm^3	Charge Diameter, mm	Relative detonation impulse, %
50/50 TNT/RDX	-	-	1.68	-	100.0
	10.0	-	0.82	30	49.8
					(48.8)*
	-	Water	1.33	30	59.9
	<0.1	-	0.82	30	48.7
	4.8-7.4	-	0.89	30	56.1
					(56.0*)
	-	Water	1.35	30	69.9
	-	Nitromethane	1.48	30	85.3
					(88.1)**
RDX	Powder (Commercial Product)	-	0.89	30	57.0
		-	1.12	30	71.9
		Water	1.49	30	80.1
	15.0	-	0.76	40	59.7
					(57.7)*
		CCl_4	1.63	40	71.2
		TNM/NB[1] 92/8	1.63	40	107.2
	-	-	-		(105.3)**
	(Commercial Product)	-	0.76	40	60.2

[1]NB-nitrobenzene

the velocities of fine-grained charges of the same explosives, their relative detonation impulses for the same charge density coincide within the limits of experimental error. Apparently only that part of the contact surface (cross section of the charge) occupied by the explosive grains participates in the transfer of impulse to the gauge. The relative impulses calculated using this assumption are shown in Table II, along with the corresponding measured values, and are indicated by single asterisks. When the voids between the grains are filled with inert liquids (H_2O, CCl_4), the relative detonation impulse increases due to slowing of the detonation-product expansion and increased duration of high-pressure action on the piston of the device. An explosive liquid filler such as nitromethane increases the relative impulse more than does an inert filler. The relative impulses calculated assuming additivity of the relative impulses in mixtures of RDX with explosive fillers are shown in Table II, indicated by double asterisks. Comparison of the experimental and calculated values shows that the condition of additivity of the relative impulse is also fulfilled for the detonation of coarse-grained charges.

The relative detonation impulse of coarse-grained charges is less than that of fine-grained ones, a fact that is related to the low poured density of the former. However, the increase in relative impulse when the spaces between the grains are filled with water, compared with that of the corresponding "dry" charges, is greater for the coarse-grained charges. Because filling coarse-grained charges with water is simpler, under field conditions, than filling fine-grained ones, in cases in which the detonation wave goes through the individual grains of the explosive, the use of coarse-grained explosives is expedient.

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