НАНОТЕХНОЛОГИИ, НАНОСТРУКТУРЫ, КВАНТОВЫЕ ЯВЛЕНИЯ. НАНОЭЛЕКТРОНИКА. ПРИБОРЫ НА КВАНТОВЫХ ЭФФЕКТАХ

THE INFLUENCE OF POWER DENSITY OF EXPLOSIVE CHARGES ON THE DETONATION NANODIAMONDS YIELD

V. Yu. Dolmatov

Federal State Unitary Enterprise "Special Design and Technological Bureau"Technologist",
St. Petersburg, Russia,
Corresponding author: V. Yu Dolmatov (diamondcentre@mail.ru)

To determine the dependence of the yield of detonation nanodiamonds (DNDs) on the power of explosives used, a new concept is introduced – the specific capacity (SC) of the explosive, equal to the ratio of the heat of explosion to the unit mass and time. For practical use, 1 kg (or 1 mole) of explosives is advisable for use as a unit of mass, and as a unit of time – 1 microsecond, commensurate with the time of the processes in the chemical reaction zone (CRZ).

The chemical reaction time is understood as the time required for the matter to move from the front of the detonation wave to the Chapman-Jouguet plane, where chemical reactions are completed. The detonation velocity of explosives and the pressure of gases in the Chapman-Jouguet plane are related to the specific capacity of explosives. The dependence of DNDs yield on the velocity of detonation and pressure in the Chapman-Jouguet plane is found. Optimum yield of DNDs (> 5 % by mass) is accounted for the specific capacity of explosives from 30000 to 60000 $\frac{kJ}{kg * \mu s}$, at a detonation velocity from 7250 to 8000 m / sec and pressure in the Chapman-Jouguet plane from 21 to 28 GPa.

Key words: detonation nanodiamonds; explosive power; pressure in Chapman-Jouguet plane; yield of nanodiamonds; detonation velocity; heat of explosion; composition of explosives.

EXPERIMENTAL AND RESULT

To date, the process of detonation nanodiamonds (DNDs) synthesis from the charges of TNT and hexogen mixture has been studied quite well, the optimal empirical values of the basic control parameters of synthesis have been known.

The composition of the charge (~ 60% of TNT and ~ 40% of hexogen), the charge density (1.6-, 1.7 g / cm^3) [1], the optimal oxygen balance (-35 ÷ -60) [1], the presence of an aqueous or water-salt charge armor [2], a non-oxidative, or better, reducing detonation medium [3]. In this case, the pressure in the chemical reaction zone (CRZ) should exceed 17 GPa, and the temperature should be at least 3000 K [4]. Nevertheless, the quantitative dependence of DNDs yield on the actual power of the mixture and individual explosives, on the pressure of products of detonation (PD) in the Chapman-Jouguet plane, and on the detonation velocity of explosive charges has not been established. The establishment of these dependencies is the goal of this paper. The most universal value for explosives, according to the author, is the determination of the classical power of explosives and the associated DNDs yield (with other things being equal). The accepted determination of explosives power in the "TNT equivalent" is a very crude estimate, which determines the work of detonation products of explosives (fougasseness and brisance of explosives) and is not suitable for scientific determination. The power, defined in explosion technology as the release of heat of explosion per unit mass, also does not allow the use of these quantities for accurate calculations and does not fit as a classical definition of power, by which is meant the allocation of energy per unit time. Under the time of energy release during the explosion, one can take the time of the chemical reaction, which is the time of passage of the explosives element and PD from the front of the detonation wave to the Champion-Jouguet plane (ie from the beginning to the end of the chemical reaction zone). This time is tenth and hundredths of a microsecond. For many practical calculations, the exact time of CRZ existence is of decisive importance, since it is possible to determine the actual power of explosives, which is very different depending on the type of explosive or their mixtures and strongly affects the DNDs yield, other things being equal. Thus, the power of explosives will for the first time be expressed as it should be: the heat of the explosion, referred to the unit of mass and unit of time, and under the time is meant 1 microsecond.

Table

The detonation process parameters of TNT-hexogen charges and tetryl

№	Name of explosive or mixture composition	OB, oxygen balance,%	P, charge density, g / cm^3	Q_{expl}, heat of explosion, kJ/kg	τ, time of chemical reaction in CRZ, μs	Power, kJ/kg*μs	DNDs yield, % wt.	D, detonation velocity, μs	Pressure in the Chapman-Jouguet plane, GPa
1	2	3	4	5	6	7	8	9	10
1	Trinitrotoluene (TNT) (casted)	-74	1,62	4232 [5,6]	0,29 [8]	14593	1,06	6850 [7]	cp.18,5 [13]
2	TH 70/30	-58,3	1,61	4684*	0,08 [8]	58550	4,7	7420 [5]	27,6 [13]
3	TH 60/40	-53,0	1,66	4835*	0,14 [8]	34540	7,2	7510 [5]	22,3 [9]
4	TH 50/50	-47,8	1,62	4944 [5]	0,13 [8]	38031	6,0	7670 [8]	24,6 [10]
5	TH 40/60	-42,6	1,66	5137*	0,11 [8]	46700	5,8	7850 [12]	26,0 [4]
6	TH 36/64 (pressed)	-40,5	1,68	5197*	0,10 [7]	51970	5,4	8000 [7]	cp.28,1 [13]
7	TH 30/70	-37,3	1,60	4969 [6]	0,08 [8]	66100	4,4	8052 [5]	21,4 [15]
8	Hexogen (RDX)	-21,6	1,68	5740 [12]	0,07 [8]	82000	1,1	8670 [12]	34,5 [12];
9	Tetryl	-47,4	1,65	4602 [5]	0,10 [7]	46000	5,6	7500 [7]	26,7 [13]

The heat of explosion of individual types of explosives and their mixtures has been determined many times and differs, depending on the method of determination and specific performers, insignificantly [5, 6], the lifetime of CRZ has been fairly accurately determined in [7, 8]. At the same time, DND yield depends strongly on the conditions for carrying out the process of detonation synthesis. All the data on DNDs yield were determined by the author of this work, and all the explosions were carried out in an Alfa-2-M explosion chamber with a capacity of 2.14 m^3, the charges were manufactured and undermined by the same operator, the detonation was carried out in the water armoring.

The table shows experimental and published data reflecting the main parameters of the detonation process of DNDs obtaining. From column No. 7, we see how much the power of explosives differs - up to ~ 6 times, in contrast to the thermal effect (the maximum difference is only 1.35 times). Part of the heat of the explosion was calculated by additivity (according to the proportional contribution of the individual explosives composing the mixture). It was previously established from the well-known thermal effects of mixed explosives that this method gives an error of 1.4–1.8%, which is insignificant.

However, the table material is difficult to perceive without a graphic display. Figure 1 shows the dependence of the yield on the power of explosives.

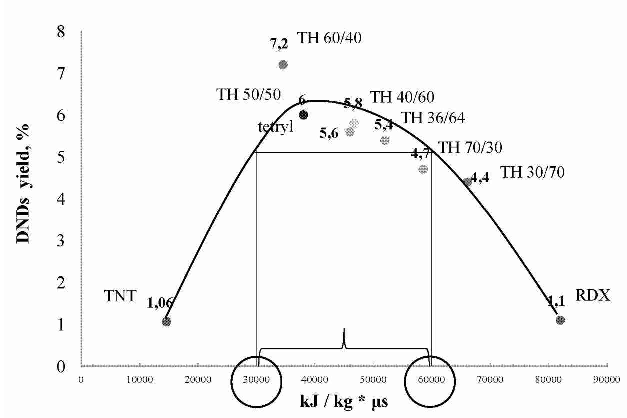

Figure 1. – Dependence of DNDs yield on the power of explosives

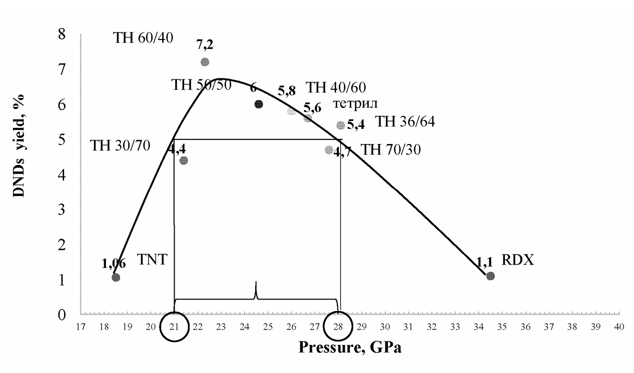

Figure 2. – Dependence of DNDs yield on pressure in the Chapman-Jouguet plane under explosive of explosions

A fairly clear dependence of the DNDs yield on the power of the explosive is seen, and if an optimal yield of DNDs is ≥ 5 % by mass, then explosives with a power in the range of 30-60 kJ / kg * μs should be used. The best result was obtained when using the composition of trotyl - hexogen (TH) 60/40, undermined in water armor. At the same time, charges of TH 50/50, TH 40/60, TH 36/64 and tetryl can be used. The use of a simpler dependence – DNDs yield on the pressure of PD in the Chapman-Jouguet plane (Figure 2) shows that the pressure of PD must be at least 21 GPa and not more than 28.5 GPa.

An even simpler dependence of DNDs yield on the detonation velocity (integral index) in Figure 3 shows that it is necessary to use explosives having a detonation velocity from 7250 to 8000 m / s. That is, knowing the detonation velocity of explosives or their mixture, it is possible to estimate DNDs yield from these products with sufficient accuracy.

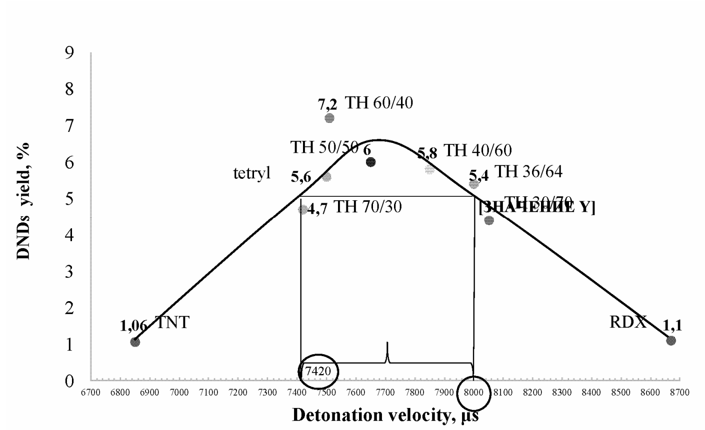

Figure 3. – Dependence of DNDs yield on the detonation velocity of explosives

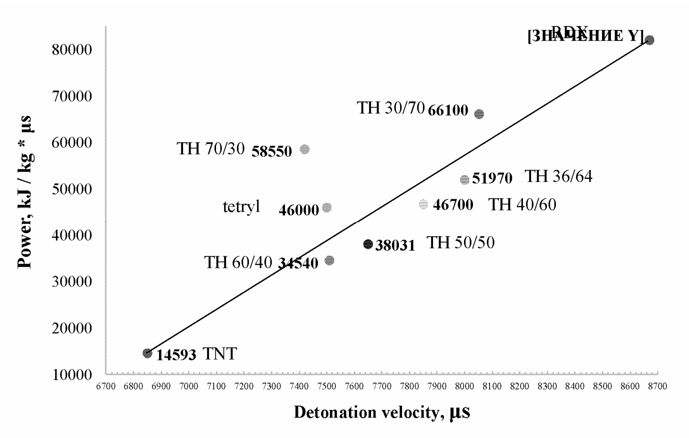

Figure 4. – Dependence of the explosive power on the detonation velocity of explosives

In Fig. 4 shows a practically directly proportional relationship between the detonation velocity of explosives and their power. Thus, knowing the detonation velocity, we can for the first time determine the power density of explosives and their compositions with sufficient accuracy. (On the other hand, we see that the power data of TH 70/30 unjustifiably fall out of this dependence, most likely the reaction time in CRZ is strongly underestimated in [8] than in the real process.)

CONCLUSION

To obtain DNDs with a stable yield of 5% or more, it is necessary that the explosives (or mixture composition) meet the following conditions:

1. The power of explosives should be from 30 to 60 thousand kJ in terms of 1 kg of explosive and 1 μs.
2. The pressure of PD in the Chapman-Zhuge plane should be in the range from 21 to 28 GPa.
3. The detonation velocity should be in the range of 7,250–8,000 microseconds.
4. The dependence of the detonation velocity on the power of the explosive is of a character close to directly proportional.

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