SIMULATION OF SHOCK WAVES FROM EXPLOSION OF MIXTURE EXPLOSIVE CHARGES

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The present paper provides the modelling of the explosion of the charges of the traditional (trotyl) and new blended explosive substances: polymix GR1/8 (74 %)+KRUK2 (26 %), compolite GS6, polymix GR4-T10. As a result of the research, it has been established that when using TNT a specific impulse is formed, which is by 40 % more than an explosion of new mixed explosives, and the safe distance from the source of the explosion of such explosives is increased by 25-50 %. On the basis of the established dependences of excess pressure, the specific impulse on the type and mass of charge, as well as the distance from the epicentre of the explosion, an engineering method has been developed for calculating dangerous parameters of the explosion impact on the environment.

Introduction

Due to an increase in volumes of mining operations and coming of quarry fields to protected ecosystems, there is a question about their safety regarding intense dynamic loads during the explosion of explosives (EX). However, blasting operations are characterised by a small coefficient of explosive energy use, an increase in the requirements of technological and environmental safety, and the economic inactivity of the use of expensive industrial EX. Therefore, in recent years several tens of new non-TNT EX mixtures have been developed. At the same time, conclusions about their technological efficiency and environmental safety are based on visual observation of experimental and practical results of explosions.

Special attention should also be devoted to the territory where, in addition to environmental problems inherent in production processes, there are other types of hazards, for example, related to the carrying out military operations (bombing, explosives of military stockpiles of ammunition, mines, the use of phosphate mines, the destruction of infrastructure of settlements, etc.). Therefore, scientists urgently raise the issue of the safety of natural-technogenic environment in the spread of airborne shock waves.

In this regard, the study of parameters of airborne shock waves (ASW) affecting the protected ecosystems in the explosions of new blended EX, and prediction of the degree of damage of technogenic systems and living organisms represent actual scientific and practical tasks.

Literature review and problem statement

As it is known, the main parameters of the airborne shock wave (ASW), which determine its destructive and damaging effect, are excess pressure ΔP, Pa; speed pressure ΔPs, Pa; specific pressure impulse I, Pa·s; time of shock wave action, τ_{+}, ms.

Excess pressure at the front of the shock wave is the main parameter that determines the destructive force of the shock wave. This is the difference between the maximum P and the atmospheric pressure P_0: $\Delta P=P-P_0$.

For the determination of excess pressure in engineering practice, various modifications of the empirical formula of M.A. Sadovsky [1], [2], used for charge of TNT, are widely implemented. For other explosives, the so-called energetic TNT-coefficient is used to determine the equivalence of the explosive. However, these formulas do not correspond to the theory of dimensions and similarity; therefore, their application can lead to unsatisfactory results.

The works of many scientists are devoted to the research into the definition and assessment of the impact of airborne shock waves. Most of the research focuses on the underground and terrestrial explosions and examines the damaging factors of a nuclear explosion. Methods for determining the individual parameters of the explosion and assessing their impressive impact on objects of the environment during the explosion are developed by Ya.M. Eisenberg, A.N. Birbaer, V.V. Boyko, O.O. Vovk, K.V.Yegupov, Yu.I. Kalyukh, M.A. Klyachko, S.V. Polyakov, Yu.I. Nemchinov, O.A. Savinov, A.E. Sargsyan, P.Z. Lugovoi, V.G. Kravets, V.S. Kukunaev, N.S. Remez, L.R. Stavnetsar, A.G. Tyapin, V.G. Bezdenkov, A.M. Trofimchuk, A.M. Uzdin, S.G. Shulman, N. Newmark, E. Rosenblueit and others.

The research of these scientists established such damaging for environment factors as funnel on the surface of the ground, the impact of the explosive shock wave, the seismic effect of the explosion on objects, the impact of the gas-dust cloud raised in the air during the explosion, thermal radiation, and the damaging effect of fragments and debris on security objects.

The studies of many scientists are devoted to the investigation of explosion damaging factors. Thus, in the publication [3], the estimation of the ASW action in an emergency explosion in the stock of ammunition is described, the main physical processes are described with the action of the ASW on surrounding objects, the basic parameters of the ASW are defined: excess pressure at the front of the ASW, impulse of pressure at the compression phase, action of the ASW and a safe distance at shock wave action. Formulas and dependences obtained in the research can be adapted and used to study an explosion case, for example, a terrorist act.

In the work by Vadulina, Achyvakov and Sanimov [4], the main bases of human life insurance during the explosion of the pipeline are considered, the dependence of the conditional probability of human damage on the change in excess pressure of the shock wave of the explosion is studied.

In the works [5]-[8], the influence of explosive lesions on the human organism is examined during technogenic catastrophes and terrorist acts.

The research by Chernozubenko, Kuprinenk and Bisik [9] provides the analysis of the damage factors on the human body after the explosion for the possibility of providing a complex system of personal protection. The distribution of injuries of body parts of military personnel during an explosion have been graphically depicted. The damage factors of the blow-ups of the explosive device have been considered, such as primary (fragments of an explosive device and a shock wave) and secondary factors (personnel fall from equipment, damage by buildings and structures, stress and heart attacks).

Study [10] helped establish the mechanogenes is of the impact of the damage factors of explosive devices on the human body. The results of the analysis showed that the main types of damage were injuries of the lower extremities, internal organs, and head.

Kryuchkova, Arzhavkina and Zhekalov in their research [11] presented results of studying dynamics of physical work ability and behavioural reactions of white rats at different intervals of the first day after damage by air shock wave of light and medium severity.

In the works by Luchko, Remez, Vorobiov, new types of EX were described [12]-[15]. The authors also compared different variants of charging pores and argued about the perspective use of these EX. However, the issue of the impact of air shock waves of new blended EX remains open.

Numerical modelling

The goal of the research is the theoretical substantiation of the parameters of air shock waves during explosions of charges of traditional and new blended EX to predict their destructive effect on the environment.

To achieve the goal, the following objectives are set:

- to carry out mathematical modelling of the process of propagation of air shock waves during explosions and their interaction with natural-technogenic ecosystems;
- to establish the mathematical dependences of parameters of air shock waves on the type and mass of the explosive and the distance from the source in order to calculate their effect on living organisms.

An explosion of the spherical charge of EX in the air is considered. The motion of detonation products and air is described by a system of differential equations that determine the laws of conservation of the amount of motion, mass and impulse [2]

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial t} + \frac{1}{\rho}\frac{\partial p}{\partial r} = 0, \tag{1}$$

$$\frac{\partial \ln \rho}{\partial t} + u\frac{\partial \ln \rho}{\partial r} + \frac{\partial u}{\partial r}\frac{Nu}{r} = 0, \tag{2}$$

$$\frac{\partial\left(\frac{p}{\rho^{\gamma}}\right)}{\partial t} + u\frac{\partial\left(\frac{p}{\rho^{\gamma}}\right)}{\partial r} = 0, \tag{3}$$

where r - coordinate, u - speed, p - pressure; t - moment of time; γ - entropy index; ρ - density.

Expansion of detonation products takes place according to binomial is entropy [2]

$$P = A\rho^{N} + B\rho^{\gamma+1} \quad (4)$$

Constants in equation (2) characterise this type of EX. The initial conditions of this task are

$$u=0,\ p=p_n,\ \rho=\rho_n \text{ at } 0 \le r < r_0, \quad (5)$$

$$u=0,\ p=0,\ \rho=\rho_0 \text{ at } r_0 \le r, \quad (6)$$

where r_0 - charge radius, p_n,ρ_n - pressure and density of detonation products in the explosion, ρ_0 - density of air.

The boundary conditions are as follows: *1* - the condition of continuity of speed u and pressure on the moving contact boundary "products of detonation - air"; *2* - the condition of "non-penetration"- the speed on the charge axis is zero. For the approximation of the system of differential equations (1)-(3) with the corresponding initial and boundary conditions, the method of finite differences was used based on the finite-difference scheme of the type "cross" [13, 16-19] of the second order of accuracy in spatial and temporal coordinates.

To calculate the effect of traditional and new blended explosives on the shock wave parameters, the following EX are studied [12-14]: trotyl, polymyx GR⅛ (74%)+KRUK2 (26%), compolite GS6, polymix GR4-T10 (Table 1).

Table 1

Parameters of Explosion of TNT and New Blended EX

EX	Parameters						
	p_n, GPa	Q, KJ/kg	γ	ρ_0, kg/m^3	A	$B \cdot 10^{-5}$	N
Trotyl	9.8	4184	1.25	1600			3.12
Polymyx GR1/8	4.54	3355.7	1.242	1000	59.35	0.604	2.48
Compolite GS6	1.75	3919.7	1.235	852	7.671	1.638	2.24
Polymix GR4-T10	2.71	3864.4	1.245	872	5.67	1.279	2.73

As a result of the numerical solution to the problem, graphic functional dependences of the change of excess pressure on the distances of the spread path for different charge radii of different types of EX were obtained. For example, in Fig. 1 r_0=0.2 m.

As a result of calculations, it is clear that excess pressure of air shock wave formed at explosion of traditional explosive substance TNT is much larger than during explosion of new blended EX.

At a distance of the air-shock wave spreadin1 m in the explosion of charges with a radius of 0.1 m and 0.2 m, the excess pressure for TNT is by 2 times greater than for new blended EX. At a distance of 1.5 m and 2 m, the difference is reduced to 90 %–75 %. At a distance of 5 m from the epicentre of the explosion, the excess pressures are almost the same. This is due to the fact that in the near area of explosion, TNT has significantly larger parameters of the explosion (pressure, density, heat of radiation, etc.), but with an increase in the distance from the explosive cavity the waves formed by the explosion of TNT expire considerably more intensively than from blended EX because in the explosion of the charges of TNT the energy losses at the front of the shock wave are much higher.

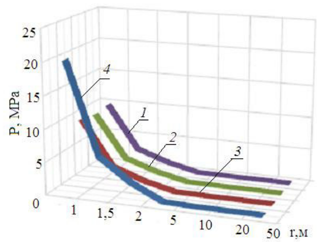

Fig. 1. Dependence of the change in excess pressure of the air shock wave on the explosion centre at r_0=0.2 m: 1 - polymix GR1/8; *2* - compolite; *3* - polymix GR4-T10; *4* - TNT

From this we can conclude that in the distant zone of the explosion, the parameters of air shock waves are weakly dependent on the type of EX, and are determined by the mass of charge.

Thus, it can be stated that a traditional explosive substance, such as TNT, forms a stronger excess pressure during the explosion, and therefore the force of destruction of surrounding objects is higher than in new blended explosives. The application of the polymix GR4-T10, the compolite GS6 and the polymix GR1/8 (74 %)+KRUK2 (26 %) during blasting works is safer in terms of excess pressure formation.

After comparing the explosion of charges of traditional and new blended EX charges with excess pressure at the shock wave front, an impulse for the same explosives was calculated. As an example, Fig.

2 shows the dependence of the impulse on excess pressure during the explosion of charges of polymix GR4-T10 with different radii.

As a result of calculations and graphic representation of the dependence of impulse on excess pressure, it is evident that with an increase in excess pressure the impulse of air shock wave increases.

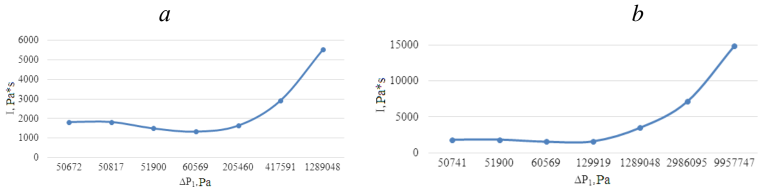

Fig. 2. Dependence of the impulse from the excess pressure in the explosion of charges of polymix GR4-T10 with different radii: *a* - at r_0=0.1 m; *b* - r_0=0,2 m

Impulse of the air shock wave formed during the explosion of a traditional explosive - TNT - is more by 40 % than during the explosion of new blended explosives for all investigated charge radii at a distance of 1 m from the epicentre of the explosion. At a distance of 1.5 m and 2 m, this difference is 30 % and 20 %, respectively. At a distance of 5 m, the value of the impulse is almost the same for charges with radii of 0.1 m and 0.2 m, but for a charge with a radius of 1 m - at a distance from the epicentre of the explosion from 1.5 m to 20 m, the difference is 40 %, and from 20 m - 20 %.

Consequently, a traditional explosive substance, such as TNT, forms a stronger impulse during the explosion, and therefore force of destruction of surrounding objects is higher than in new blended explosives. The application of the polymix GR4-T10, the compolite GS6 and the polymix GR1/8 (74 %)+KRUK2 (26 %) during blasting works is safer from the point of view of impulse formation.

The results of calculations of excess pressure were compared with the characteristics of the destruction of structures at the explosion of TNT and the new mixed explosives, depending on the distance of the propagation wave and the radius of charge (Tables 2, 3).

Table 2

Destruction (damage) of elements of constructures sensitive to maximum excess pressure at TNT explosion

Elements of constructures	Nature of destruction (damage)	ΔP_1, Pa	Explosive wave propagation distance, r_H, m		
			r_0=0, 1m	r_0=0,2 m	r_0=1m
1	2	3	4	5	6
Windows (large and small)	Glass beating; possible destruction of window frames	35000-70000	5 and more	10 and more	more 50
Lightweight wall filling with wavy asbestos panels.	Destruction	70000-140000	5	6,5-10	50
Wavy steel and aluminum panels	Disruption of connections with subsequent severe deformation	70000-140000	5	6,5-10	50
Brick walls of 20 - 30.5 cm thick (without reinforcement)	Destruction caused by shear deformation and displacement	490000-560000	1,5-2	3,5	17-18
Wall paneling made of wooden panels (standard design houses)	Disruption of connections and failure of wooden panels	70000-140000	5	6,5-10	50
Concrete or slag concrete walls of 20-30,5 cm thick (without reinforcement)	Destruction of the walls	140000-210000	2,5-3	5-6	25-31,5
Light ground vaulted structures made of corrugated steel panels of 6 - 7.5 m long, with thickness of soil shattering over 0.9 m above the vault	Complete destruction	2450000-2800000	1 and less	2	10,5-11
	Damage to the part of the vault from the side facing the explosion	2100000-2450000	less 1	2	11-11,5
	Deformation of end walls and arch; can damage the front door	1400000-1750000	1-1,5	2,5	25-27
	Damage to the ventilation system and the front door	70000-100000	5	6,5-8	50
Lightweight concrete ground or recessed shelter with soil crumbling at least 0.9 m thick (panels of 5-7.5 cm thick); beams are located at a distance of 1.2 m	Destruction of building	2100000-2450000	less 1	2	11-11,5
	Partly destruction of building	1750000-2100000	1-1,5	2-2,5	25-31,5
	Deformation of panels, formation of a large number	1000000-1750000	1-1,5	2,5	12-14

from each other	of cracks, depressions into separate panels				
	Formation of cracks, can cause damage to the front door	70000-100000	5	6,5-8	50
Planes on the ground	Complete destruction	420000	1,5-2	3-3,5	19-19,5
	Damage when restoration is not economic feasible	280000	2-2,5	4	22,5
	The plane needs major repairs to restore	210000	2,2-3	4,5	25-25,5
	No repair or minor one is required	70000	5	9,5-10	50

Table 3

Destruction (damage) of elements of constructures sensitive to maximum excess pressure at new EX explosion

Elements of constructures	Nature of destruction (damage)	ΔP_1, Pa	Explosive wave propagation distance, r_H, m		
			r_0= 0,1 m	r_0= 0,2 m	r_0= 1 m
1	2	3	4	5	6
Windows (large and small)	Glass beating; possible destruction of window frames	35000-70000	5-50	10-50	50 and more
Lightweight wall filling with wavy asbestos panels.	Destruction	70000-140000	2,5-4	5-8	24-40
Wavy steel and aluminum panels	Disruption of connections with subsequent severe deformation	70000-140000	2,5-4	5-8	24-40
Brick walls of 20 - 30.5 cm thick (without reinforcement)	Destruction caused by shear deformation and displacement	490000-560000	1,5	2,5-3	14-14,5
Wall paneling made of wooden panels (standard design houses)	Disruption of connections and failure of wooden panels	70000-140000	2,5-4	5-8	24-40
Concrete or slag concrete walls of 20-30,5 cm thick (without reinforcement)	Destruction of the walls	140000-210000	2	4-4,5	20

Light ground vaulted structures made of corrugated steel panels of 6 - 7.5 m long, with thickness of soil shattering over 0.9 m above the vault	Complete destruction	2450000-2800000	less 1	3,5	8,5-9
	Damage to the part of the vault from the side facing the explosion	2100000-2450000	less 1	4	9-9,5
	Deformation of end walls and arch; can damage the front door	1400000-1750000	less 1	4,5	10-10,5
	Damage to the ventilation system and the front door	70000-100000	2,5-3	6-8	29-40
Lightweight concrete ground or recessed shelter with soil crumbling at least 0.9 m thick; beams are located at a distance of 1.2 m from each other	Destruction of building	2100000-2450000	less 1	4	9-9,5
	Partly destruction of building	1750000-2100000	2	4-4,5	20
	Deformation of panels, formation of a large number of cracks, depressions into separate panels	1000000-1750000	1	5	10-11,5
	Formation of cracks, can cause damage to the front door	70000-100000	less 1	4,5-8	29-40
Planes on the ground	Complete destruction	420000	1,5	3	15,5
	Damage when restoration of plane is not economically feasible	280000	1,5-2	3,5	18
	The plane needs major repairs to restore	210000	2	4	20
	No repair or minor repair and replacement is required	70000	4	8	40

Comparison of the results of the calculations of the excess pressure formed during explosion of the TNT and the new mixed explosives indicates that, if the same pressure is generated with the same EX radius, the distance at which the structures are destroyed is more than for TNT. For example, when the walls are destroyed by the pressure of 140000-210000 Pa at r_0=0.1 m, the explosion of new EX occurs at a distance of 2 m, and during the explosion - at a distance of 2.5-3 m.

Thus, the use of explosives such as polymix GR4-T10, compolite GS6, and polymix GR⅛ (74%)+KRUK2 (26%) is safer to maintain the integrity of structures at greater distances.

Table 4 presents the results of calculations of the dependence of the degree of damage to people during the explosion of TNT and new blended EX on the distance of the spread of an explosive wave for different charge radii.

Table 4

The Degree of Damage to People in the Explosion of Different EX

Degree of damage	ΔP_1, Pa	Spread of an explosive wave, r_H, m (*)		
		r_0=0.1 m	r_0=0.2 m	r_0=1m
1	2	3	4	5
Death of people as a direct effect of ASW Death of people under the ruins of buildings Death of people as a result of smite from solid objects	190000	2.5-3 3-3.5	5-6 5,5-6,8	25-31,5 47-48
Serious damage as a result of ASW action Serious damage when the building collapses or the body moves by an explosive wave	69000-76000	4.5-6 4.7-7.8	9.5-10.5 7.3-8.5	49.5-50.5 more than 50
Serious damage as a result of eardrums and lungs under action of an explosive wave Defeat by fragments and ruins of the building	55000	8-9 10-11	16-16.5 more than 50	more than 50
Defeat by fragments and ruins of the building. Probability of rupture of drum chambers 10 %	24000	more than 50	more than 50	more than 50
Temporary loss of hearing or injuries as a result of secondary effects of an explosive wave (collapse of the building and body transference) Fatal or serious damage from direct exposure of an explosive wave is unlikely	16000	more than 50	more than 50	more than 50
Injuries associated with the destruction of glass and damage to the walls of the building	5900–8300	more than 50	more than 50	more than 50

* The numerator contains data for the TNT, in the denominator – for new compound substances.

From Table 4, it can be concluded that the use of such a traditional explosive like TNT is more dangerous to human health than the use of new blended explosives, as, for example, the death of people as a result of direct exposure to ASW from the time of the explosion of EX with r_0=0.1 m at an excess pressure of 190 KPa for TNT will take place at a distance of 2.5-3 m, and during the explosion of new blended EX - at a distance of 3-3.5 m.

In work [20] with the experimental data, the degree of contusions (DC) in dogs caused by the action of air shock waves was analyzed, which came with the following values of maximum and average pressure. At the same time, the authors proposed the use of parameter $P_{ср}=I_{уд}/t$, equal to the ratio of the specific impulse to the time of action of the ASW because the spread of experimental data is much smaller than for P_{max}. In order to assess the damage of people in the explosion of EX, in emergencies or terrorist acts, it is important to assess the likelihood of getting a damage from the ASW and the degree of contusion, and the most acceptable is the class of parametric laws of damage (PLD) using the Weibull-Gnedenko distribution. To solve this problem, the recalculation of the degree of concussion at certain parameters of air shock waves was performed in the research.

For practical application of theoretical results of the spread of ASW and their effects on environment, the method of calculating the safe parameters of the explosion was developed.

To construct dependence of $P_{ср}$ from relative distance calculations were carried out, for example, for TNT they are given in Table 5.

Table 5

Dependence of the pressure on the relative distance for TNT

r,м	$\sqrt[3]{m}\frac{}{}r$			ΔP_{cp}, *Pa*		
	m=6,7kg	m=13,4kg	m=6702kg	m=6.7kg	m=13.4kg	m=6702kg
1	1.885	2.375	18.848	$2.6\cdot10^6$	$20.13\cdot10^6$	$2.5\cdot10^9$
1.5	1.26	1.58	10.57	$0.8\cdot10^6$	$6\cdot10^6$	$7.44\cdot10^8$
2	0.943	1.188	9.424	$0.36\cdot10^6$	$2.6\cdot10^6$	$3.14\cdot10^8$
5	0.38	0.48	3.77	$70.7\cdot10^3$	$211\cdot10^3$	$2\cdot10^7$
10	0.19	0.24	1.9	$53\cdot10^3$	$60.7\cdot10^3$	$2.56\cdot10^6$
20	0.095	0.12	0.95	$50.9\cdot10^3$	$53.2\cdot10^3$	$0.36\cdot10^6$

On the basis of the established dependences of excess pressure, specific impulse from type and mass of EX, as well as distance from the source of the explosion, nomogram to determine the distances or masses of EX, safe for living organisms was built (Fig.3): *1* - trotyl, 2 - polymix GR⅛ (74%)+KRUK2 (26%), *3* - compolite GS6, *4* - polymix GR4-T10. Following degrees of concussion are marked: 1 - light, *2* - medium, *3* - hard, *4* - difficult edge, *5* - death.

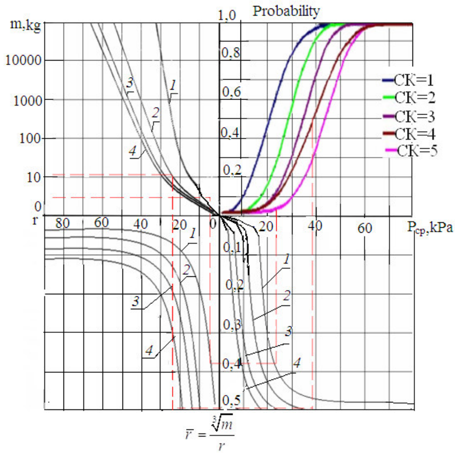

Fig. 3. Nomogram to determine the safe parameters of explosion of different EX for dogs, rabbits, pigs: *1* - trotyl; *2* - polymix GR⅛ (74 %)+KRUK2 (26 %); *3* - the compolite GS6; *4* - the polymix GR4-T10

Figure 4 presents nomograms for determining safe parameters of explosion for people in explosion of charges of different types of EX. Numbering of curves in Fig.4 corresponds to the numbering of Fig.3.

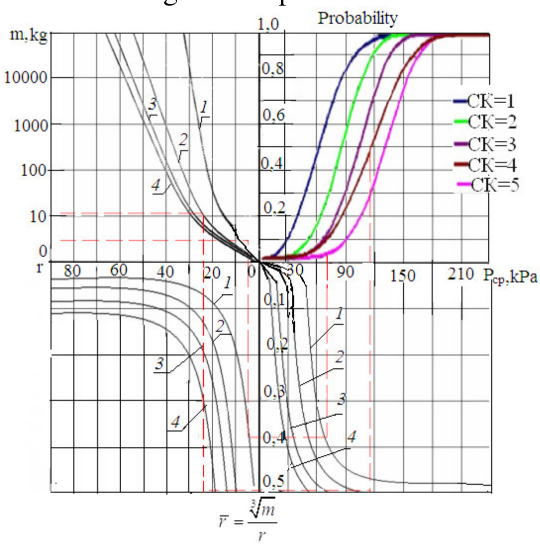

Fig. 4. Nomogram to determine the safe parameters of explosion of different EX for people: *1* – trotyl, *2* – polymix GR⅛ (74 %)+KRUK2 (26 %), *3* – the compolite GS6, *4* – the polymix GR4-T10

Results and discussion

As it is known, the main parameters of the air shock wave, which determine its destructive and striking effect, are excess pressure, speed pressure, specific impulse of pressure and action time of the positive phase of the shock wave.

Today, new non-TNT blended EX, the technical and economic efficiency of which is proven, become a widespread practice. However, there is no theoretical substantiation of the environmental safety of the use of these EX and the interaction of airborne explosive waves during explosive operations with elements of ecosystems.

On the basis of mathematical modelling, the research investigates the dependence of the change in parameters of air airborne explosive waves on the mass of charge of explosive at different distances from the epicentre of the explosion. For a charge weighting10 kg, the following dependences for the ASW parameters are established, i.e., for the TNT: excess pressure $y = 9901.3x^{0.7034}$, pressure of the speed throng $y=423.12x^{1.301}$, specific impulse $y=0.63x^{0.6667}$, action time of the positive phase of the wave $y=4.6171x^{0.1667}$; for the polymix GR4-T10: excess pressure $y=7932.4x^{0.647}$, pressure of the speed throng $y=250.87x^{1.2262}$; for the compolite GS6: excess pressure $y=7932.4x^{0.647}$, pressure of the speed throng $y=250.87x^{1.2262}$; for the polymix GR⅛ (74 %)+KRUK2 (26 %): excess pressure $y=7457.5x^{0.636}$, pressure of the speed throng $y=218.73x^{1.211}$.

For a charge weighting 50 kg, the following dependences for the ASW parameters are established, i.e., for the TNT: excess pressure $y=4\cdot10^{6}x^{-1,53s}$, pressure of the speed throng $y=5\cdot10^{7}x^{-2,00s}$, specific impulse $y=85,545x^{-1}$, action time of the positive phase of the wave $y=2,8025x^{-0,5}$; for the polymix GR4-T10: excess pressure $y=2\cdot10^{6}x^{-1,424}$, pressure of the speed throng $y=1\cdot10^{7}x^{-2.803}$; for the compolite GS6: excess pressure $y=2\cdot10^{6}x^{-1.426}$, pressure of the speed throng $y=1\cdot10^{7}x^{-2.806}$; for the polymix GR⅛8 (74 %)+KRUK2 (26 %): excess pressure $y=2\cdot10^{6}x^{-1.407}$, pressure of the speed throng $y=1\cdot10^{7}x^{-2.772}$.

Based on the comparison of the calculated results and the degree of damage we have, the use of an explosive such as TNT is more dangerous to human health than the use of new blended explosives because, for example, the death of people as a result of direct influence of ASW in explosion of EX with r_0=0.1 m at an excess pressure of 190 KPa for

TNT takes place at a distance of 2.5-3 m, while during the explosion of new blended EX -at a distance of 3-3.5 m.

Based on the established dependences of excess pressure, specific impulse from the type and mass of charge of EX, as well as the distance from the epicentre of the explosion, an engineering method was developed for calculating the dangerous parameters of the explosion on the environment.

Conclusions

1. The effective calculation method based on numerical simulation of the explosion of spherical charges of traditional and new explosives in the air has been developed, which allows obtaining the parameters of airborne shock waves, depending on time, distance, mass of charge and type of EX.

2. Based on the mathematical modelling of the spread of airborne shock waves and their interaction with natural-technogenic environment, the influence of traditional and new blended explosives on the parameters of ASW has been studied. As a result of numerical calculations, it has been established that during the explosion of charges of traditional EX (trotyl), a stronger excess pressure (by an average 85 %) than in the new blended EX is formed. Consequently, the use of the polymix GR4-T10, compolite GS6 and polymix GR⅛(74 %)+KRUK2 (26 %) during blasting works is safer in terms of excess pressure formation.

3. The functional (degree) dependences of excess pressure on the distance of the source of the explosion and the charge and impulse mass on the excess pressure and the charge radius for different types of EX have been determined.

4. It has been established that with an increase in excess pressure, the impulse of the airborne shock wave increases. When using TNT, a specific impulse is generated, which is much stronger (by 40 %) than that of blasting new blended explosives.

5. It has been established that the destructive and damaging effect of the explosion charge of TNT is much greater than of the new blended EX. The safe distance from the source of the explosion of such charges increases by25-50 %.

6. The engineering methodology has been developed for calculat-

ing the dangerous parameters of the explosion on the environment based on the established dependences of excess pressure, specific impulse on the type and mass of charge of EX, as well as the distance from the epicentre of the explosion.

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