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STRUCTURAL ELEMENTS OF A LOW-SPEED NON-ELECTRIC INITIATION SYSTEM IN THE IMPLEMENTATION OF DOWNHOLE DECELERATIONS

The processes of initiation of explosives and structural elements of a low-speed non-electric initiation system are studied. Advantages and disadvantages of BC-based initiation systems and low-speed detonating waveguide based on the detonation characteristics of the elements of these systems are considered in the light of short-delay blasting problems. It is substantiated that unlike DC, modern low-growth non-electric detonation transfer systems provide technological efficiency and explosion safety. It has been experimentally proved that when using detonating waveguides, the importance of using reliable splitter designs, providing simultaneous capless transmission of the detonation process over a distance, increases.

Keywords: explosive, initiation, low-velocity detonation, detonating waveguide, detonating cord, structural elements

1. Introduction. The process of chemical transformation of explosives, accompanied by the formation of a detonation wave with the transition of its energy in the shock wave, depends largely on the completeness of the charge detonation, which is determined by the density of charging, charge structure, features of the initiation and conduct of blasting technology.

The phenomenon of detonation damping burning explosives or complete failure of the detonation can be attributed to changes in the regime of detonation under the influence of the type and power of the initiator [1], with the physical properties of the explosive in the charge, the nature of the mutual charges location in the system, the ratio between the diameter of the charge and the charge generation, priority of the explosion charges and parts charges when initiating the cascade.

A number of causes of incomplete detonation and burning of explosives in boreholes, among which are the low density of the charging, the presence of radial clearance (channel effect), compaction charges for group blasting under the influence of shock waves generated by the explosion of related charges, i.e., acoustic interaction between charges. The consequence of a collision or sequential action of shock waves can be both explosive compaction in the charge and shear of the charge parts in the borehole or in a borehole blasting cartridge with the deterioration of the propagation conditions of detonation process [2]. Deformation of explosives in charge, as well as detonators, with compression waves from the explosion of the neighboring charges or portions of charges leads to loss of the ability of the detonation of explosives and detonators initiating ability.

2. The objectives of the study. It is known that the structure of charges, circuits, their location in the system and the sequence of explosion determine the choice of the means of initiation. The combination of these elements blasting system should provide both the necessary degree of destruction of the rock mass, and the reliability of operation of the system of charges that is the basis for the successful application of known methods of initiation. At the same time the combination of methods used to initiate charges of systems of various construction do not always give positive results. This is due to the fact that during the formation of the charges at the respective means of initiation is not included the character of the detonation process depending on design elements, and initiator charge. Therefore, rationale of the mechanism of the detonation process in the explosion of charges of different designs (continuous, diffuse, with axial clearance, etc.) in conjunction with elements of the system adopted by the initiation represents an important scientific - applied problem.

Frequently used in domestic practice the way of initiation based on detonating cord sufficiently fully demonstrated not only its advantages but also disadvantages. The latter should include the need to develop and apply the same mass explosion of a certain assortment of detonating cords. This will ensure:

– reliable transmission of the initiating pulse from detonator to charge;

– the minimum intensity of the air shock wave of the explosion of terrestrial mainline and the precinct chains of the detonating cord;

– protection of downhill charge of the mix of explosive compaction in the explosion downhole lengths of detonating cord, leading to the bottom charge;

– eliminate the formation of channels in the material stemming designed for reliable locking of the explosion products in the initial stage of its development.

The need for a sufficiently wide assortment of detonating cord does not complicate the process of its production, but creates difficulties at the stage of conducting charging works with various types of cords. However, the use of detonating cord as a means of high-speed transmission of the initiating pulse between the parts of the dispersed charge allows actually using in the blasting technique factor interaction of shock waves in the microsecond regime decelerations that is not available in other, less high-speed modes of transmission of the initiating pulse.

Considering that the ways and means of initiation are critical in ensuring the technological efficacy and safety of explosives, their improvement and development has received significant attention. The experience of industrialized countries - the main consumers of industrial explosives and their means of initiation with respect to mining technology shows an advantageous development of the non-electric initiation systems of industrial charges, based on the displacement channel of shock waves, the most famous of which is the system of "Nonel". It has high security, ease of use, ensures trouble-free blasting in very difficult geological conditions and allows you to make the circuit short-delay blasting with wide ranges decelerations intervals. Notable features and benefits of foreign systems such as "Nonel" are typical for Russian analogue "Edilean," and for the domestic non-electric system, one of which is the system of "Impulse". Practical application of the domestic version of the tubular shock-rube and appropriate means of switching and transmission impulse detonation preceded by careful consideration of both the manufacturing system technology elements [3], as well as laboratory studies and range of its reliability and efficiency in practical application [4].

3. Investigation of the initiation of explosives and components low-speed non-electric initiation system. Significant advantages of the detonation wave guides are made in non-electric initiation system flexibility, allowing almost the first time in large quantities for a long time to master the proven benefits of initiating a cascade of distributed charges, as well as technology in the initiation of counter contour blasting and monoliths separation during extraction of block stone. The absence of side damage waveguide ensures that the set of physical characteristics tamping and the charge, and powerful enough pressure jump at the outlet of the waveguide tube (about 2.5 - 3.0 MPa) ensures reliable operation of the transmission capsule or pulse adjoint waveguide coaxial segment.

Consider the advantages and disadvantages of initiation systems based on the detonating cord and shock-tube based on detonating characteristics of detonating elements of these systems on the basis of short-delay blasting problems, for example, initiating a cascade borehole charges. Mass implementation of the method of downhole decelerations until shock-tubes was impractical because it required the initiation of the bottom part of the distributed downhole charge. In the case of the electrical initiation technology decelerations element - capsule - electric detonator needed to be placed at the bottom of the charge, which is not permitted by applicable regulations. Using blasting of detonating cord requires the use of low power amplification with species in the initiation to guarantee its initiation. Application tubular detonating waveguides instead of detonating cord simplifies the task of the bottom charge initiation, but should be compared possible methods in terms of consistency of the detonation process in parts dispersed charge or in portions of the continuous borehole charge with the time difference application specific initiation signals and their respective rate inherent in various methods.

Technique of multipoint initiation or cascade elongated charges involves optimization of the number of points of initiation in solid charge or the degree of dispersion of the charge using inert gaps. The result of applying this method is the multiple loading of inhomogeneous rock mass at different points in the horizontal and vertical planes of the destroyed volume. Cascade initiation charges are dispersed inert or solid column gaps, and the sequence and direction of detonation and explosion mechanical effect associated with the speed ratios of the initiator of detonation, an initiating pulse is applied torque and velocity of the detonation process in the explosive charge.

Using pulse to quantify various explosive charge blasts in cascade relationship [5]:

$$i_{max} = \Sigma\, 0{,}087\, \rho_{ввi}\, d^2\, t\ ,$$

where $n_ч$ – the number of parts of explosives on the length of the charge, $\rho_{вв}$ – explosive density, d – detonation velocity, t – pulse duration.

Calculated pulse magnitude and duration for continuous elongated charges of, grammonite, granulated ammonite number 6ZHV and igdanite, as well as for the combined explosive charges. Structurally, the charges represented the column of 8 m in length, consisting of a homogeneous explosive, or a combination of two pairs of explosives sequentially placed on the column. The length of a single charge area was 1.3 m.

Calculations and experimental studies with the definition of the explosion crater radius when initiating a cascade revealed that the optimal combination of explosive on power and time parameters are presented pulse pairs ammonite number 6ZHV + igdanite, grammonit + igdanit and ammonium number 6ZHV + grammonit. Maximum explosion crater radius is achieved when the number of pairs $n = 3$.

By excluding from consideration unsafe electrical method initiating charge column parts, analyze the possibility and feasibility of using detonating cord and shock-tube. The essence of the cascade initiation is to achieve a particular sequence collision of detonation waves in the charge and shock waves in the rock. If a charge is applied, alternately folded portions of highly sensitive and low sensitivity explosives application for initiation of standard detonating cord leads to the initial detonation in pairs powerful explosives by detonating cord and then to the low sensitivity of these explosives, not detonating by the detonating cord. In general, the charge explodes "cascade" to provide the collision of shock waves in the rock, increasing about 1.6 times the maximum compressive stress [6] and the emergence of intense shear stresses. Based on the direction and velocity of detonation ratio of detonating cord and different parts of the explosive charge, the venue fronts of shock-tube should be below the level of the middle period of the weak explosive (Figure 1). It does not take into account the presence along the whole charge the weaker signal generated by the detonating cord.

The initiation is directly related to the influence of the detonating cord on a more powerful explosive, proceeding from the geometrical constructions in Figs.1 in the detonation velocity detonating cord is 8000 m/sec and low sensitivity explosive 2500 m/sec detonation process in the bottom of the latter will start (1.3 m / 8000 m/sec) = 163 ms later than the upper part thereof. During this time the detonation wave front from the upper end of the insensitive explosive is at a speed of 2500 m/sec charge spread axis (0.000163 sec × 2500 m/sec) = 0.41 m. Meeting tapered edges 1 and 2 occurs at a distance of 0.86 m or over 344 ms after the onset of detonation. At the same time the front of the shock wave 1 in the rock mass at the level of the upper end portion of insensitive explosive is removed from the normal charge axis by 2 m, front YV 2 at a distance of 1.05 m.

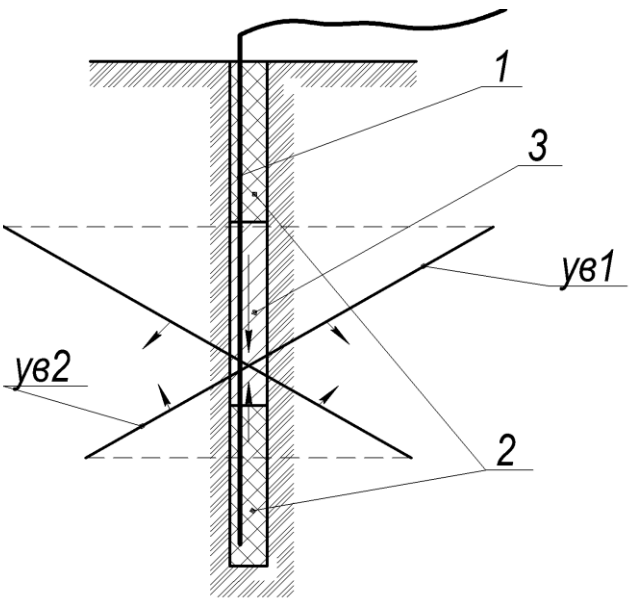

Figure 1. The sequence of the detonation process of the cascade initiation by detonating cord. 1 – detonating cord; 2 – powerful explosive charge; 3 – insensitive explosive charge; YV1 (ув1), YV2(ув2) - colliding shock fronts.

These calculations give an idea of the spatial – temporal parameters detonation process in cascade initiation, namely, that the charge-charge interaction of the cascade in each pair comes on the wave level within a microsecond time slots at a distance from the charge axis, not exceeding half the distance between the charges. In an explosion of charges (groups) their interference is minimized, and therefore, decreases the likelihood of acoustic interaction between shock and detonation waves that can adversely affect the development of the detonation process in the related charges, leading to burnout and explosive failures.

The implementation of this scheme cascade blasting using reverse circuit development process, i.e. bottom initiating charge, require the use of detonating cord with a reduced consumption of explosives till initiation, because the bottom location of the detonator detonating cord staff inevitably creates the conditions for a consistent initiating starting from the top of the charge sensitive detonating cord parts of the cascade. Then, from the bottom upwards initiation require regular spacer segment of detonating cord that can initiate appropriate portions of the charge. Naturally, such a switching circuit complicates the charging process due to the increased consumption of detonating cord.

Variant scheme with rare intervals is interesting not only in terms of a simple explosive consumption for crushing, but also due to changes in spatial – temporal pattern of distribution of wave fronts. If the velocity of propagation of the acoustic signal by inert material is about 400 m/sec, the meeting place of conical fronts YV 1 and YV 2 in the range of inert gap is not substantially moved. However, due to a substantial difference in the speeds YV within the inert interval and in rock fronts meeting angle approaches 0°, which is accompanied by increase of tensile stress intensity.

Experienced explosions [5] demonstrated that the optimum length rare spacing is 1.0-1.2 m at total height of 10.0 m column charge, and the optimal amount of inert gaps $n_{un} = 2$. Industrial explosions in the quarries have shown that in the presence of charges 1 - 3 gaps crushing array improves significantly – a 20% increasing output of fine fractions and a 41% reduced output oversize. However, difficulties with the application of reverse initiation of the charge in this process are preserved, especially with regard to the probability of failure of individual parts of the charge due to compaction staff detonating cord.

In this connection, it should consider the possibilities of the modern method of initiation using non-electrical systems of "Nonel" [7]. The decisive advantage of the shock-tube is the lack of side effects on the coring charge or its elements are composed of various explosives. However, it is necessary to solve the problem of shock-tube growth rate, since each pair in each stage or part of the dispersed inert charge intervals downhole require separate feed shock-tube segment to a detonator for initiating an initiating pulse in a predetermined sequence.

Modern blast technique solves this problem by using sliding intermediate detonators [8], allows applying the scheme downhole decelerations with the introduction of a system of "Nonel" low-energy detonating cord, transmitting an initiation impulse to the branch of the tubular shock-tube with an intermediate detonator short-delay actions placed in a holder. Due to complexity schemes using high speed detonating cord transmission timing pulse initiating the process are reduced. But, at the same time the use of millisecond decelerations within the borehole eliminates the possibility of interaction of charges in the acoustic mode, creates the prerequisites for their interaction on the level of movement that creates the risk of the mechanical deformation related charges with the possibility of partial compaction and therefore burn or failure. Therefore, based on the principle of interaction of the borehole of the charge on the wave level, should be used in an action movie blasting caps - instantaneous intermediate detonators.

At the reverse initiation of the charge downhole initiating pulse is applied to the bottom of the charge for shock-tube, and further up the charge using a combination of the initiator of the staff of the detonating cord and the required number of intermediate detonators. For the closest approach the process of the initiation of high-speed mode of interaction of fronts it should reduce the length of the rare gaps to a minimum, according to experimental data 0.2 m.

The practice of short-delay blasting systems, solid borehole charges during mass explosion involves primarily their loading to the location of the two intermediate detonators at the top and bottom of the charge. If intermediate detonators are used with a standard length of shock-tube segments, i.e. proceed from the equality of the shock-tube segments of bringing the initial momentum of the line for both fighters, the flow of shock-tube with two-point initiation is doubled. Thus, when the depth of the borehole 14 meters and charge has a length of 10 m, the length of the interval shock-tube is 16 meters and the total length of shock-tube is 32 m.

If the result of the upper waveguide length is in accordance with the depth of laying the upper intermediate detonator, the total length of the shock tube will be reduced to 22 m (Figure 2a). However, due to the significant difference in the speeds of the pipe-detonation shock and explosive (respectively 2000 and 4000 m/sec) in the charge detonation front overtake incoming initiating pulse through the waveguide to the bottom of the intermediate detonator, i.e. interaction of detonation fronts in charge is excluded. The problem can be solved with the use of the transmitting device that is called double of the splitter (Figure 2b.). Location of the splitter on the waveguide is dictated only by the designated place of detonation wave fronts meet the height of the charge and the techniques of its installation in combination with the waveguide and intermediate detonators. For example, if the meeting place of the shock fronts generated by the individual sections of the downhole charge provided at its middle, a splitter installed at this level, with a total consumption of shock-tube would be about 20 m. The value of the splitter increases substantially in cascade initiating charge or disperse inert intervals.

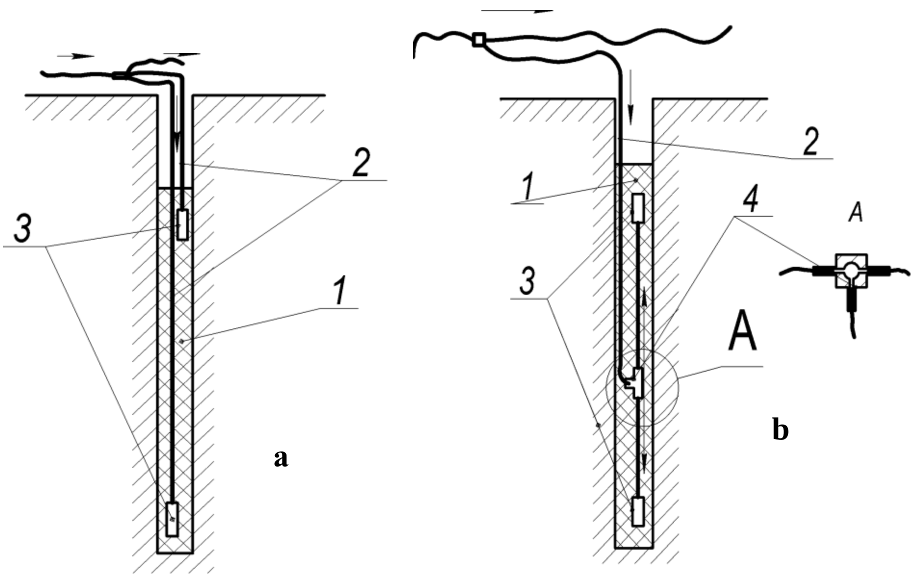

Figure 2. Schemes of initiation of a downhole charge: a – separate segments of the shock-tube; b – a splitter.
1 – explosive charge; 2 – shock-tube; 3 – intermediate detonator; 4 – splitter.

According to the scheme in Figure 3, subject to the initiation of the bottom of the borehole in series of three parts of the charge without using splitters initiating impulse to be fed from the line on a stand-alone waveguides, and to provide reverse sequence initiating the length of the segment of shock-tube should grow with the approach of the charge to the surface. The total consumption of shock-tube in a switching scheme will be about 50 meters per borehole. When switching to commutation "through splitter" (Figure 3, b) the flow of shock-tube is reduced to 25 - 30 m.

In connection with the above it is necessary to draw attention to the need for improving and expanding the range of basic and auxiliary means of non-electric initiation. This will serve the further development of safe and effective methods and schemes short-delay blasting at mass explosions using as a basic initiator system of domestic shock-tube.

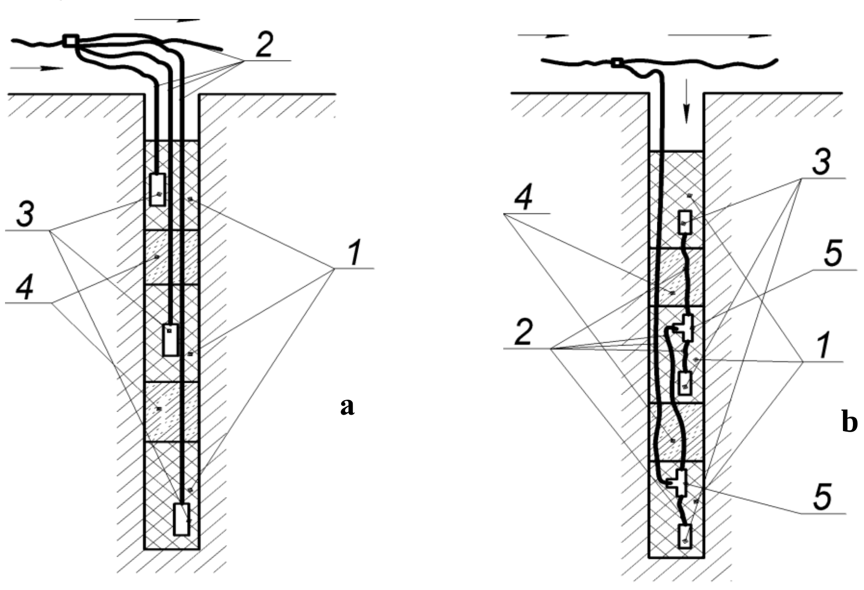

Figure 3. Scheme of the lower parts of the initiation of the dispersed charge: a – the individual segments of the shock-tube; b – with the use of splitters.
1 – charge; 2 – shock-tube; 3 – intermediate detonator; 4 – gap; 5 – splitter.

4. Conclusions. The choice of means of mass initiation of charges is determined by several factors such as the construction of charges, circuits of their location in the system, the sequence of blasting triggering reliability of the circuit and the charge in the system, the required degree of destruction of the array, the exclusion of undesirable effects on the environment, economic indicators.

An important condition for the harmonization of these factors in the process of blasting rock mass is a study of the mechanism of the detonation process of the charges and the system as a whole in conjunction with the elements adopted by the initiation system.

Unlike detonating cord modern non-electric technological systems provide efficacy and safety of the explosion. Their versatility in terms of technology is the possibility of using downhole decelerations without certain difficulties and limitations associated with the use of detonating cord while excluding the probability of interaction of acoustic shock and detonation waves in related charges system. This increases the value of the use of reliable construction splitters providing simultaneous detonation capsule transmission of the detonation process from active branches in parallel mounted initiated by detonating waveguide segments through the efficient use of energy shock-tube output of its end part.

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Quyudaxili sürətin azaldılması zamanı aşağı sürətli, qeyri elektrik təsir sisteminin konstruktiv elementləri

Partlayıcı maddələrin təsirlənməsi və aşağı sürətli, qeyri elektrik təsir sisteminin konstruktiv elementləri tədqiq edilmişdir. Qısamüddətli sürəti azaldılmış partlayış nöqteyi nəzərindən detonasiya kabelləri (DK) vasitəsi ilə yaradılan təsir sistemlərinin, aşağı sürətli detonasiya dalğa ötürücülərinin bu sistemlərin elementlərinin detonasiya xarakteristikalarını nəzərə almaqla üstünlükləri və çatışmayan cəhətlərinə baxılmışdır. DK-lardan fərqli olaraq detonasiyanın müasir aşağı sürətli, qeyri elektrik ötürülməsi sistemləri texnoloji cəhətdən və partlayış təhlükəsizliyi cəhətdən daha üstündürlər və təhlükəsizdirlər. Eksperimentlər vasitəsi ilə detonasiya dalğa ötürücülərindən istifadə zamanı etibarlı konstruktiv budaqlanmalardan istifadə etməyin əhəmiyyətinin artdığı, detonasiya prosesinin müxtəlif məsafələrə kapsulsuz ötürülməsinin mümkünlüyü təsdiq edilmişdir.

Açar sözlər: partlayıcı maddə, təsir, aşağı sürətli detonasiya, detonasiya edici dalğa ötürücüsü, detonasiya kabeli, konstruktiv elementlər

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Конструктивные элементы низкоскоростной неэлектрической системы инициирования при реализации внутрискважинных замедлений

Исследованы процессы инициирования ВВ и конструктивных элементов низкоскоростной неэлектрической системы инициирования. Рассмотрены преимущества и недостатки систем инициирования на основе ДШ и низкоскоростного детонирующего волновода исходя из детонационных характеристик элементов этих систем в свете задач короткозамедленного взрывания. Обосновано, что в отличие от ДШ современные низкоскоростные неэлектрические системы передачи детонации обеспечивают технологическую эффективность и безопасность взрыва. Экспериментально доказано, что при использовании детонирующих волноводов возрастает значение применения надежных конструкций разветвителей, обеспечивающих одновременную бескапсюльную передачу детонационного процесса на расстояние.

Ключевые слова: взрывчатое вещество, инициирование, низкоскоростная детонация, детонирующий волновод, детонирующий шнур, конструкционные элементы

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