Sensitivity of the heat-resistant igniter composition and its initiation mechanism parameters during impact

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Abstract. The presented paper describes the results of a study of an initiation mechanism of heat-resistant igniter composition from deformation processes perspective during impact and depending on various factors. Characteristics are identified and nature of deformation processes, which occur in a period before explosion, is investigated. Recommendations are developed for an improvement of explosion safety and fire safety of a processing technology of promising substances with high energy output, and conditions of its safe implementation as initiating charge in detonating cap are justified.

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Introduction

Nowadays, heat-resistant igniter composition produced according to specification TU-7276-177-07513406-2001 (in following – HRIC) is used in electric spark igniter of industrial electrical blasting caps of ED-Z-T type. Preliminary tests of HRIC as an initiating charge of detonating cap (DC) showed that it is capable to initiate detonation of RDX (hexogen) explosive charge. It raises a question about a possibility of HRIC application as initiating charge, and, in the first place, about safety of its use in more severe conditions. In particular, those conditions imply impact. In connection with that, the purpose of the presented research is a study of HRIC initiation during mechanical action, a development of recommendations for an improvement of safety of its processing technology and an application of it as initiating charge.

In order to develop recommendations, which are aimed at an exclusion of hazardous conditions, the system analysis was conducted of relationships, connecting properties of HRIC and influencing factors, such as, typical mechanical action on a charge of explosive material (EM); deformation processes, occurring in tested specimen; mechanisms of an explosion initiation, realized as a result of deformation; sensitivity for external impulses during testing of substances; safety during operations of technological processing and reliability as a part of finished product during an application [1].

As a practical implementation of theoretical concepts about emerge of warm-up sites, an evaluation method of impact sensitivity assessment through minimal action energy (Emin) with a consideration of combustion (explosion) spread is implemented [2-4]. The values of Emin are determined with optimal ratios of minimal (critical) diameter of the ball's contact area and thickness of a layer (D/h) [5]. With an increase of impact's energy and a penetration of the ball in a layer of HRIC, spherical contact surface increases, at the same time a set of effective deformation processes is realized with various ratios P = f (D/h), where, P – critical pressure, corresponding with dangerous conditions. A similar relationship can be proposed for elastic-brittle destruction and in a relation with impact energy: Emin = f (D/h).

Figure 1 shows a relationship of frequency and impact energy, which was obtained using with K-44-IM impact-testing machine.

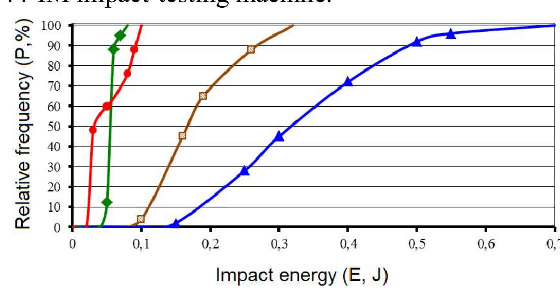

Fig. 1. Impact sensitivity measured with K-44-IM impact-testing machine:

1- Resistant igniter composition; 2- Lead azid; 3- Tetrazen; 4- Regular igniter composition

Figure 2 shows generalized scheme of specimens' deformation during testing with K-44-IM impact-testing machine, where:

A – initial position;

B – after ~ 300 microseconds after contact with ball's load;

C – after ~ 500 microseconds;

D – after ~ 550 microseconds.

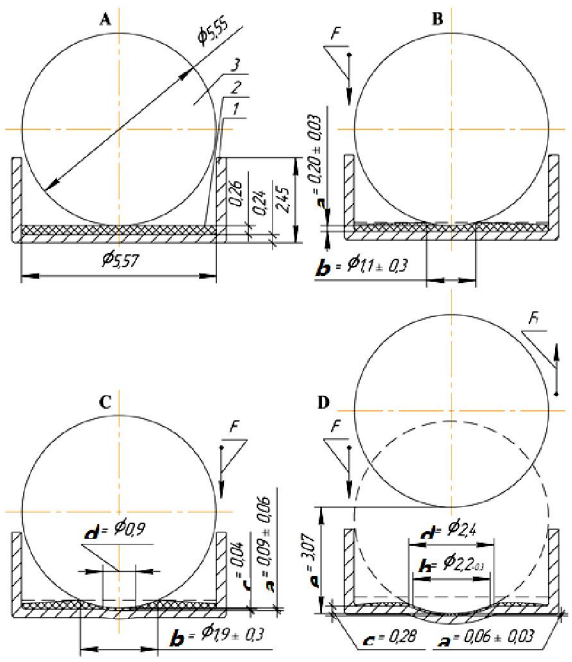

Fig. 2. Scheme of processes occurring in a pre-explosion site at impact:
1 – cup; 2 – HRIC sample; 3 – ball; F and F1 – directions of movement and rebound of the ball; a – width of the gap between the ball and the bottom surface of cup (press formed cup); b – base diameter of ball contact segment and critical deformation zone; c – depth of cup; d – diameter of cup; e – height of rebound of the ball.

Initially, the ball deforms the charge. Then through a refined layer of sample it reaches the bottom of the cup and deforms it, forming deepening and, in fact, conduct an initiation of charge or lead to initiation failure. As a result of the experiments it was established, that with little energy of action (up to 0.12 J), explosive transformation of HRIC occurs according to a mechanism of destruction and outflow in free space between surface of the ball and the side walls of the cup, in the initial period of the ball's movement, which only starts to deform the layer of the charge (after ~ 300 microseconds after contact with the ball's load).With medium energy of action (up to 0.25 J) explosive transformation is initiated in the moment of the cup's deformation (~500 microseconds after contact with the ball's load), that is an initiation occurs at the end of loading. Flowing of the charge's layer of the critical thickness with high speed and under increasing resistance from the narrow gap between the ball and formed hole in the bottom of the cup leads to warming up of sample up to a critical temperature of ignition.

Figure 3 shows a typical picture of a condition of the charge and the cup after impact tests with an absence of explosion.

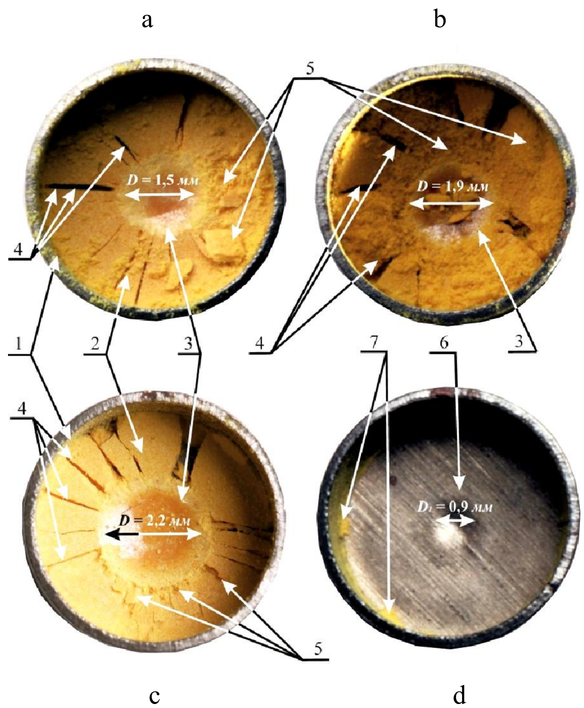

Fig. 3. Characteristics residual picture of HRIC samples after testing
a, b: hsb = 3.5 cm, V = 0.83 m/s, E = 0.17 J;
c, d: hsb = 5 cm, V = 0.99 m/s, E = 0.25 J
1 – cup; 2 – HRIC sample; 3 – impress of the ball (D – deformation zone); 4 – brittle fracture of specimens; 5 – fragments of HRIC; 6 – hole in the bottom of the cup (press formed cup); 7 – HRIC particles remaining after the stress relaxation and elastic ejection of the sample from the cup.

During testing at the upper limit (E = 0.32 J), full actuation of testing samples occurs in a form of explosive combustion.A development of an initiation occurs in a form of dustair cloud in a stream of fine particles of HRIC moving with a high speed during their tearing from the surface of the charge and the cup.

Modeling of hazardous situation during production, which was related with an initiation of dustair mixtures consisting of EM fine particles, was carried out during testing of bulk and combined charges. As a result the most hazardous conditions were identified, a reduction of minimum energy of initiating impact (0.1 ... 0.07) J, in the case of of a presence of an addition in a combined charge of HRIC.

Results of the experiments for a determination of a relationship between frequency of HRIC initiation near lower limit and speed of impact at an optimal D/h = 3.1 shown that with the same energies of action (0.07 J) and speed of impact (0.54 m/s and 0.83 m/s) has no effect on frequency.

During the experiments safe maximum of energy E max = 0.07 J at D/h = 3.1, as well as minimal energy of initiating impact E min = 0.1 J at d/h = 4.6 are determined. With an increase of D/h, i.e. a decrease of the layer thickness below critical (0.26 mm), flashes are occurring with an increase of energy of mechanical pulse (0.1 ... 0.5) J, however, development of the process is not observed. With a decrease of D/h, energy required for the destruction of the charge decreases to (0.15 ... 0.1) J, but explosion does not occur, in that case it is necessary to use more energy (0.15 ... 0.5) J, which is used to obtain an optimum thickness (6). The relationship between energy of impact and thickness of the layer, as well as a presence of minimum of energy at the optimal D/h ratios is a consequence of two deformation processes, which are responsible for an initiation of brittle fracture and plastic deformation [7]. Change of conditions of testing allows a transfer of one process into another [8].

The obtained results indicate that the initiation mechanism is of ambiguous nature, which results from parameters of external actions and occurs depending on conditions of the mechanical pulse application. Dangerous factors in mechanical methods of HRIC processing are conditions of a localization of plastic flow (deformation), in addition, risk rises sharply with a presence of fine particles in test assembly, which requires maximum attention and consideration of technological processes of HRIC recycling and its use as initiating charge.

The conducted set of experiments allows to state, that, complying technological regimes for operations of lead azide pressing in DC shell, a possibility of local incidents with HRIC as initiating charge will not exceed acceptable standard limits [9, 10]. The recommendations on an exclusion of dangerous conditions, of technological and operational safety will serve as experimentally defined safe and minimum parameters of HRIC initiation, including those which depend on various factors.

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