

ABSTRACT

to the dissertation for the degree of Doctor of Philosophy (PhD) in the specialty “6D073400 - Chemical technology of explosives and pyrotechnics» of Pustovalov Igor Anatolyevich “Physical and chemical foundations and technological principles of industrial explosives mixtures identification”

The relevance of the theme of dissertation research investigation

Lack of proper regulating of industrial explosive cycle leads to regular increasing illegal use of industrial explosives for criminal and terrorist purposes.

Currently, the most popular requirements for regulating of industrial explosives cycle are licensing, permission or other similar requirements for their storage, use, transportation, sale and purchase and other commercial activities. These requirements don't guarantee total control, based on the fact that "criminal elements" tend to obtain explosives from the most available origins and least risky source regions, causing evident concern areas are theft or diversion of legitimate stocks of industrial explosives at the stages of production, transportation, storage and use.

Thus, the proposition of current concern is to provide the possibility of marking (labeling) of industrial explosives in the stage of their production with the help of secret marking additives, that will allow either to identify explosive materials, using technical means, or decrypt the type of detected explosives, their manufacturer and other important information.

The purpose and tasks of the research

The main goal of current thesis work appears in the development of chemical compositions for using them as marking additives of industrial explosives, pyrotechnic (gas generating, slowing-down) compositions. Development of methods for encrypting information in a microcarrier, injecting a microcarrier into mixed explosives and industrial pyrotechnic (gas generating, slowing-down) compositions with various structures and subsequent identification by qualitative and quantitative methods of analysis.

To achieve the goal in the thesis, the following tasks were set:

1. Investigation of chemical compositions based on polymethylsiloxanes to specify their marking properties;
2. Elaboration of marking compositions based on mixtures of 1,4-bis (1,3,5-trimethylphenylamino) anthraquinone, nigrosine, 4-diethylaminoazobenzene and 5-hydroxy-3-methyl-4 (2,4-dimethylphenylazo) -1-phenylpyrazole, which possess specific marking properties for visualization of the explosive and determination of the necessary identification information;
3. Approbation of industrial explosives composite formulation with marking additives in the manufacturing environments of Kazakhstan factories;
4. Identification of explosives and pyrotechnic compositions, containing in their mixture marking chemical additives, by the technical means of chromatographic analysis, X-ray and mass spectroscopy, as well as scanning microscopy and designation of the most accurate and effective physical and

chemical methods for identifying industrial explosives, gas-generating compositions (retarders as well);

5. Laboratory and firing ground experimentation of the safety criteria for explosive and pyrotechnic (gas generating, slowing-down) compositions, comprising marking additives.

Object of the research

The object of the research are industrial mixed explosives and pyrotechnic (gas generating, slowing-down) compositions, containing in their structure ammonium and sodium nitrates, sodium perchlorate, monohydrates, thiocarbonate, paraffins, acetate buffer solution, aluminum powder, sodium nitrite, which also have the high sensitivity to the external influence.

Subject of the research

The subject of the research are the basic mechanisms of the processes of labeling explosive and pyrotechnic (gas generating, slowing-down) compositions based on ammonium nitrate, liquid petroleum products, energetic metals and emulsion dispersions using organic substances as markers, and the principles of physical and chemical methods for the subsequent identification of the marking composition in the structure of explosive composite formulation.

Theoretical and methodological base of the research

The theoretical and methodological base of the research was derived from the main points of the national innovation systems concept. The dissertation research investigation was based on the studies of foreign and local scientists and researchers. The dissertation was consolidated with the legal acts of the Republic of Kazakhstan and the Eurasian Economic Commission, relating to the circulation of industrial explosive and pyrotechnic compositions, manifesto and methodological development of international organizations as well.

The dissertation research investigation was carried out on the basis of the following research methods: scanning electron microscopy, X-ray fluorescence analysis, chromatographic analysis, IR spectroscopy, method for determining the combustion temperature, thermogravimetric analysis, physical and mechanical methods of destructive testing.

Information base of the study

The information base of the study was derived from the statistical datum of the Eurasian Economic Commission, the Blasting Work Council under the Committee for Industrial Development and Industrial Safety of the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan, the International Civil Aviation Organization ICAO, the United Nations, the Anti-Terrorism Center of the National Security Committee of the Republic of Kazakhstan, reports of international and local associations in the field of blasting, expert assessments of more than 10 researchers according to the dissertation profile, as well as materials of scientific and practical conferences, periodical press and Internet resources.

Scientific originality

The results below were obtained for the first time ever by the author while doing the research investigation:

- multiunit compositions of polymethylsiloxane markers were obtained, identified in the explosive mixtures by the means of wavelength fixation methods in the visible and UV spectral regions.

- the overriding terms of marking chemical additives homogeneous distribution from 0.01 to 0.1% in the composition of multicomponent explosive mixtures for industrial use were instituted;

- a marking composition based on organic compounds has been developed, which allows to identify a substance as explosive visually and allows to establish information about its origin, using physical and chemical methods of analysis, as well;

- for the first time ever a concealing marking (labeling) of industrial multicomponent explosive mixtures, which are highly sensitive to external influences, has been carried out during manufacturing without changing the process specification;

- effective methods, based on the intensity of absorption at various concentrations and optical densities, have been developed for identifying industrial explosive and pyrotechnic (gas generating, slowing-down) compositions, marked with organic substances.

Key statements to pass on the defense of the thesis

1. The marking composition, containing information about the explosive, can be identified by gas-liquid chromatography, infrared spectroscopy and X-ray fluorescence analysis either in the ingredients of the mixed explosive and pyrotechnic compositions, or in fragments, left over the area after the explosion.

2. The forthputting of dyes C₃₂H₃₀N₂O₂, C₁₈H₁₈N₄O, C₂₉H₂₄N₆ and C₁₆H₁₉N₃ as a marking composition for mixed explosives permits to identify these substances as explosives unambiguously, using chromatography and spectroscopy methods.

3. Labeling compositions based on PMX-200, PMS-10 polymethylsiloxane liquids and C₃₂H₃₀N₂O₂, C₁₈H₁₈N₄O, C₂₉H₂₄N₆, C₁₆H₁₉N₃ fat-soluble dyes can be injected into mixed explosive compositions, using different methods of their preparation, without disrupting technological processes.

Theoretical and practical value of the study results

In the dissertation, scientifically grounded criteria are presented, which determine the choice of chemical compositions with marking properties, methods for injecting marking additives into explosive compositions and their subsequent identification are established, the absence of negative influence of marking additives on the operational characteristics of explosive and pyrotechnic (gas generating, slowing-down) compositions is confirmed, including their safe exploitation during blasting.

A technology for injecting marking additives into the compositions of

multicomponent explosives without disrupting the manufacturing process has been developed.

The elaborated marking additives do not have the adverse effect on application characteristics of explosive and pyrotechnic (gas generating, slowing-down) compositions, including particularly but not exclusively their safe use, and they have a period of their validity far exceeding the shelf life of explosive compositions based on ammonium nitrate, liquid fuel and emulsion compositions.

The relationship of current work with other research projects

The theme of the dissertation “Physical and chemical foundations and technological principles of industrial explosives mixtures identification”, was performed in accordance with the requirements of Article 4 of the Technical Regulation of the Customs Union “On the safety of explosives and products based on them” (TR CU 028/2012), approved by the decision of the Eurasian Board Economic Commission of December 25, 2012 No. 297.

Approbation of the investigation results

The materials of the dissertation were reported and discussed during various international symposia and foreign conferences:

- “XV All-Russian with international participation school seminar on structural macrokinetics for young scientists named after academician L.G. Merzhanova” (Chernogolovka, Russia, November 22-24, 2017);
- Conference “26th ICDERS” (Boston, USA, July 30 - August 4, 2017);
- X International Symposium “Physics and Chemistry of Carbon and Nanoenergy Materials” (Almaty, Kazakhstan, September 12-14, 2018);
- “The International Carbon Conference 2019” (Lexington, Kentucky, USA July 14-19, 2019).

Publication of research results

The key results of the dissertation were published in 15 publications, among them were 7 articles included in the Scopus database, 3 publications were published in editions, recommended by the Committee of regulating education and science sector of the Republic of Kazakhstan, 5 - in collections of international symposia and foreign conferences, an innovative patent and copyright certificate were received as well.

The structure and the scope of the dissertation

The structure of the dissertation sets forth the logic, the investigation operation order and algorithm for achieving the performance targets. The dissertation consists of contents, notation and abbreviations, introduction, five sections, conclusion, list of references and two appendices.

The dissertation is presented on 123 pages and includes 65 figures and 27 tables. The work consists of introduction, literature review, description of objects and research methods, results and discussions, conclusion and list of used sources, containing 121 points.