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The relevance of this dissertation topic is determined by the development of industrial emulsion explosives (hereinafter referred to as IEE), including improvements to their emulsion matrix, changes in raw materials, and sensitizing agents, which is leading to the emergence of new emulsion explosive compositions on the market. The use of industrial explosives (hereinafter referred to as IEE) increased by 25% from 2017 to 2024, from 1.8 million tons to 2.4 million tons, with IEE accounting for at least 1.5 million tons. Along with the increase in use, emissions of toxic explosion products also increase. Mining consistently ranks first in pollutant emissions into the atmosphere, the main ones being carbon and nitrogen oxides. In 2024 alone, 6.7 million tons of pollutants were emitted into the atmosphere as a result of this type of activity. To assess the safety of explosives (hereinafter referred to as explosives) used in industry, the "volume of harmful gases in explosion products" indicator must be determined in accordance with the mandatory procedure established by the Decision of the Council of the Eurasian Economic Commission dated 20.07.2012 No. 57 "On the adoption of the technical regulations of the Customs Union "On the safety of explosives and products based on them" (together with "TR CU 028/2012. Technical regulations of the Customs Union. On the safety of explosives and products based on them"). This is consistent with international practice, according to which the total amount of toxic gases is determined, reduced to the specific amount of conventional carbon monoxide. This parameter, first introduced by B.D. Rossi in the 19th century and used in mine ventilation calculations, was called "gas hazard". It is currently mentioned in domestic regulations, for example, in Rostekhnadzor Order No. 507 of December 8, 2020, "On Approval of Federal Norms and Rules in Industrial Safety 'Safety Rules in Coal Mines.'" However, a unified, approved method for determining the quantity of harmful gases after blasting operations—namely, nitrogen oxides and carbon monoxide, classified as the most hazardous gases according to Rostekhnadzor Order No. 506 of December 8, 2020, "On Approval of Federal Norms and Rules in Industrial Safety 'Instructions for Aerological Safety in Coal Mines'"—is still lacking, despite research dating back to the 1930s.

Currently, there is no unified approach to measuring the composition and quantity of explosion products. Field tests are characterized by variable conditions and a significant number of factors influencing experimental data. Calculation methods do not account for the heterogeneous nature of the compositions under consideration. Laboratory experiments are challenging to conduct safely and take into account the limiting characteristics of explosive compositions, such as critical diameter. This necessitates further experiments to determine the specific formation of explosion products and to confirm the completeness of detonation processes. As a result, experimental prediction of the composition of explosion products during the development of high-explosive explosives is difficult, standardized methods are lacking, and generalized recommendations for the development and optimization of emulsion explosive compositions are nonexistent. This work aims to advance the development of a unified methodology for the development of such compositions.

Objective of the work: To develop methodological recommendations for the development of environmentally friendly and effective high-energy emulsion explosive compositions, including those that take into account their gas hazards.

Research tasks:

To examine existing approaches to formulating high-energy emulsion explosive compositions.

To develop a laboratory rig for testing model high-energy emulsion explosive compositions.

To confirm the convergence and applicability of the results of small-scale laboratory tests of the gas hazards of high-energy emulsion explosive compositions with the results of other experimental methods.

To analyze the influence of formulation components and sensitizer on the detonation characteristics and gas hazards of high-energy emulsion explosive compositions.

To substantiate the possibility of reducing gas hazards while maintaining detonation characteristics by optimizing the formulations of high-energy emulsion explosive compositions and varying the sensitizer, using a model composition as an example. Confirm the effectiveness of optimized formulations of high-energy emulsion explosives by measuring detonation characteristics using an electromagnetic method.

Develop recommendations for developing and improving existing formulations of high-energy emulsion explosives with sufficient effectiveness and low gas hazard.

Academic novelty:

For the first time, the compositions of the detonation products of high-energy emulsion explosives (HEE) have been experimentally obtained in a nitrogen atmosphere, eliminating their secondary transformations upon contact with the atmosphere.

For the first time, a shift in the actual minimum gas harmfulness from the calculated gross stoichiometric ratio has been experimentally demonstrated, caused by the specific features of chemical reactions in the heterogeneous structure of the emulsion matrix of the high-energy emulsion explosive compositions under consideration.

Based on an assessment of the contact area of the emulsion matrix with the sensitizer, as well as the results of measurements of the detonation parameters and the composition of the explosion products for high-energy emulsion explosive compositions with various sensitization methods, a justification for the observed features of the detonation process in HEE is proposed. This justification takes into account the combined effects of the emulsion matrix composition and the type of sensitizer.

For the first time, optimization criteria for emulsion explosive composition formulations have been developed, simultaneously taking into account the gas harmfulness parameter and the detonation characteristics of the final composition.

Theoretical and practical significance

– A new approach to the experimental laboratory determination of the gas hazards of high-energy emulsion explosive compositions is proposed using a developed laboratory setup based on a Bichel bomb with charges of small diameter and mass;

– Technical principles enabling the control of the formation of hazardous explosion products when using high-energy emulsion explosive compositions are established;

– Optimization criteria for formulations of high-energy emulsion explosive compositions are proposed and substantiated, which help reduce the formation of hazardous explosion products released into the environment while maintaining the effectiveness of the resulting detonation characteristics, and their values are determined;

– Based on the optimization criteria, recommendations for the creation and improvement of existing formulations of high-energy emulsion explosive compositions are developed.

– The results of the work can be used to develop a unified methodology for the development of high-energy emulsion explosive compositions, which will take into account not only the important performance characteristics but also their impact on the environment.

Postulates presented in the thesis:

1. Based on the convergence of the explosion product analysis results with published data using the developed methodology, the feasibility of studying the gas hazards of high-energy emulsion explosive compositions through laboratory testing of small charges in small-volume explosion chambers is experimentally confirmed.

2. The existence of an oxygen balance region of the emulsion matrix corresponding to the minimum gas hazard of high-energy emulsion explosive compositions, different from the gross stoichiometric ratio of components, is substantiated and experimentally confirmed.

3. The effect of a sensitizer on the gas hazards of high-energy emulsion explosive compositions in different oxygen balance regions is experimentally demonstrated.

4. The independence of the composition of the resulting explosion products in the oxygen balance range corresponding to the minimum gas hazard from the microstructure of the high-energy emulsion explosive compositions under consideration is experimentally demonstrated.

5. Optimization criteria for existing high-energy emulsion explosive compositions have been developed, allowing for a reduction in their gas hazard without compromising their detonation characteristics.

6. Recommendations have been developed to complement existing approaches to formulating high-energy emulsion explosive compositions, taking into account the influence of components on gas hazard.