ANNOTATION

on the doctoral dissertation of PhD student
of specialty 6D073400 – "Chemical technology of explosives and pyrotechnics"

Abdrakova Fedosya Yurievna on the topic
"Development of compositions for shock wave absorption in emergency explosions".

The dissertation is devoted to the development and research of new flame-extingushing compositions based on systems of ammonium chloride and carbon dioxide ammonium, sodium sulphate crystallogyrate, sodium and potassium nitrates with additives of combustible magnesium and aluminium components, also used as additives to gas-forming agents in the form of activated carbon of various morphology and origin.

The calculated indices of combustion processes of energy-intensive systems with gasification additives have been determined. Experimental studies of combustion processes of gas-generating cartridges of flame arresters with combustible nanocarbon additives were conducted.

The parameters of the energy per unit volume of explosion products have been determined in order to obtain the condition of preventing the ignition of the methane and air mixture. Formulations of effective flame arresters with low-speed detonation at decomposition have been optimized.

The critical values of thermal characteristics of explosion from interaction of explosion products (shock and air waves) with medium (BB, charge) and from conditions of explosion of charges causing ignition of mine environment have been determined. The linear rate of combustion of safety explosives in a flame-retardant medium in a subsonic combustion chamber in a methane-air medium has been investigated.

The first chapter is devoted to a literary review of the conditions of underground gas and dust explosions in the atmosphere of mine workings, the mechanisms of explosion of gas and dust explosions of mine gases, explosion and flammability of coal. The analysis of systems of explosion suppression by passive barriers and the use of safety explosives in the mine environments has been conducted. The analysis of carried out similar works in Russia, Ukraine and China, where automatic systems of explosion suppression and localization of explosions are used.

The setting of tasks and methods of research are due to the need to protect underground mines from methane and coal dust explosions in coal mines of the Republic of Kazakhstan. Such explosions of gas and coal dust are among the most serious social and economic accidents. They are often accompanied by group accidents, sometimes claiming hundreds of lives.

The second chapter of the paper presents research methodologies, including the use of «Terra» programs for calculations, as well as physico-chemical and technical methods of research, methods of determination of temperature, pressure and speed.

The third chapter presents studies of energy-intensive compounds with gas-forming components. With the increase in the energy-intensive composition of the amount of $C_3H_6N_6$, $(C_2H_4O)_x$, $(NH_2)_2C{=}N{—}C{=}N$, the combustion temperature T increases to 2924 K with the ratio of components NH_4NO_3/Mg/C: 65/20/15. The heat of the explosive conversion reaches Q_{exp} = 314.43 J/kgk at increases in the gas forming components. In the result of the study, a gas-generating composition with nanocarbon (300 nm) and nano-aluminum (30-80 nm) is produced. The burning rate is 1.25 mm/s. The flash point of the flame arrester was 430 ^{0}C and the minimum impact flash sensitivity was 0.02 MPa.

The fourth chapter develops a chemical gas generator composition: smokeless gunpowder - Mg - colloxylin-KNO_3, which has a low-speed detonation capacity, which is sufficient for explosion absorption up to 30 MPa. Model pyrotechnic compositions based on various oxidants (ammonium chloride and carbon dioxide, sodium and potassium nitrates and sodium sulphate crystalline ohydrate) with low-speed detonation at the same fraction were investigated.

In the fifth chapter, the pilot mode investigated the explosion pulse in coal mines and the process of its attenuation when interacting with water fog. The test results showed that the mean overpressure in the three sections was reduced by 38.8%, 26.67% and 19.2% respectively, Linear burning rate of safety explosives in a flame-out medium in a subsonic combustion chamber in a methane-air atmosphere was investigated.

Chapter six defines the ignition behaviour of flame arresters with an explosion heat of 1200-1500 kJ/kg relative to combustible mine environments. Critical conditions for reducing shock waves in the model combustion chamber have been established. The critical significance of the thermal characteristics of the explosion from the interaction of the explosion products (shock and air waves) with the medium (paraffin) with the penetration of the target to a depth of 3 to 6.5 mm, with the thickness of the water barrier up to 50 mm and the conditions of the explosion of charges, igniting the mine environment.

Relevance of the research topic. The development of the coal industry involves the development of deeper layers, the application of more productive technologies and mechanisms with their increasing energy intensity, which leads to an increase in the intensity of gas and dust separation in mines, and increasing the likelihood of the emergence of different sources of ignition, i.e. increasing the factors contributing to explosions.

Protecting underground mines from methane and coal dust explosions remains the most important task in the complex of measures to ensure the safety of mining workers in underground mining. The major man-made disasters that have occurred in recent years in coal mines of coal-producing countries confirm this.

These circumstances make it necessary to improve the whole complex of explosion protection of coal mines, including means of localization of explosions (outbreaks) of methane and coal dust, in the direction of a sharp reduction in the number of developed explosions of gas and coal dust in the workings, this would eliminate the associated injuries to miners and material damage.

Purpose of the research:

Development of energy-intensive compositions for explosion protection of coal mines with localization of probable explosions of gas and coal dust.

Research objectives:

1. Theoretical and experimental determination of limits of ignition, concentration of combustible, oxidant, volume of released gases and heat of explosive conversion of energy-intensive compositions with gaseous components. Determination of optimal compositions of flame arresters with additives of nanoaluminum and carbon with high specific gas production.
2. Optimization of the model composition of effective flame arresters capable of cooling explosion products by absorbing heat on evaporation, decomposition, dehydration: ammonium chloride and carbon dioxide, sodium and potassium nitrates and sodium sulfate crystalline hydrate.
3. The prospect of using an artificial high-pressure water barrier as a method of localizing an explosion pulse in a closed space of tunnels and shafts. Determination of the explosion impulse and the process of its attenuation when interacting with water fog.
4. Determination of the optimal energy-intensive composition, which allows localizing the propagation of the flame front in mines during the interaction of explosion products (shock-air waves) and water barrier with methane and coal dust.

Research methods

The following research methods were used to solve the tasks necessary to achieve the set goals: thermodynamic calculation using the Terra program, thermogravimetric analysis, method for determining the combustion rate, X-ray phase analysis, scanning electron microscopy, method for determining the combustion temperature, polygon studies, chromatographic analysis to determine the composition of gaseous products.

The main provisions of the dissertation, submitted for defense:

- Energy-intensive composition s NH_4NO_3/Mg/C: 65/20/15, where C - ($C_3H_6N_6$, $(C_2H_4O)_x$, $(NH_2)_2C=N-C=N$), with the heat of explosive conversion Q_{exp} = 314.43 J/kgK, burning temperature - T gas composition increased; with a gas composition of 2980, Nano Al -5; Nano C -15 with dimension (C -80-100 nm, Al- 30-80 nm), characterized by flash point of flame arrester - 430 0C, minimum flash sensitivity on impact up to 0.02 MPa.
- Gas generator composition: smokeless gunpowder - Mg - colloxylin-KNO_3 detonation capacity, which is enough to blast up to 30 MPa. Gas-generating flame arresters with inorganic constituents (1 ammonium chloride, 2 ammonium carbon dioxide, 3 sodium nitrate, 4 - potassium nitrate, 5 - sodium sulfate crystallizer) with low-speed detonation and flame inhibition up to 1.25 mm/s.
- Pilot tests of water-damping localization of explosion pulses in confined spaces in coal mining mines with a decrease of average excess pressure in three sections by 38.8%, 26.67% and 19.2%, respectively. The fire extinguishers with an explosion heat of 1200-1500 kJ/kg relative to combustible mine environments.

- Regularities of the shock reduction technology in the model combustion chamber through determination of critical value of thermal characteristics of explosion from interaction of explosion products (shock-air waves) with medium (paraffin) with penetration of target to depth of 3 to 6,5 mm, with a water barrier thickness of up to 50 mm and from the explosion conditions of the charges causing the mine environment to ignite.

The scientific novelty of the results of the dissertation consists in the development of a new energy-intensive composition with a flame extinguishing effect, which is characterized by the following aspects:

1. Development of a formulation of energy-intensive compositions of flame suppressors based on gas-generating compositions of ammonium chloride and carbon dioxide ammonium with a high combustion rate;

2. Modification of classic energy-intensive flame suppressors with Alex nanoaluminum, with the study of the influence of recipe factors in the presence of gasifying agents in the form of activated carbon of different morphology and nature of origin;

3. Determination of the ignition effect of an explosion with respect to combustible mine environment by determining the excess pressure factor of the shock wave.

These energy-intensive compositions can be used not only to localize the shock wave, but also as a means for extinguishing energy-intensive formulations.

Practical significance of the results obtained

In the creation of a protective flame-retardant environment not in the source of the ignition, but in the way of the spread of the flame front, in order to prevent the development of a methane explosion into a coal dust explosion. Since the involvement of large amounts of combustible dust, if left unchecked, can become an avalanche-like explosion of an increasingly powerful mixture of dust and methane, eventually leading to a detonation explosion with enormous destructive force, which can cause enormous economic losses and loss of human resources.

This work relates to the development of science and technology in the field of production of gas generators used for explosion protection in mines hazardous to gas and dust, research is aimed at finding chemical compositions for suppressing fires in closed rooms (underground coal mines, instrument compartments, electric cabinets, warehouse and production premises, in railway cars, etc.)

For the socio-economic development of the Republic of Kazakhstan, the need to develop scientific foundations and create new technologies in the mining industry and mine development is now becoming obvious.

Work testing

The dissertation materials were reported and discussed at various international symposiums and foreign conferences:

Mater. VIII International sumposium. «Burning and Plasmochemistry» and International Scientific and Technical Conference «Energy Efficiency-2015» (Almaty, Kazakhstan, 2015); IX International Symposium «Physics and Chemistry of Carbon Materials/ Nanotechnology» and International Conference «Nanoenergy Materials and

Nanoenergy» (Almaty, September 12-14, 2016); Theses report. X International Symposium «Physics and Chemistry of Carbon and Nanoelectric Materials» Almaty, -2018; Carbon July 15-19, 2019. Lexington, USA; 3rd World Conference on Technology, Innovation and Entrepreneurship (WOCTINE) June 21-23, 2019. Istanbul, Turkey; Proceeding of the 10 th International Beremzhanov congress on chemistry and chemical technology. - Almaty, 2019; III International Scientific and Practical Conference «Science and Business -2021) - Almaty, - 2021 ; XII International Symposium Combustion and plasmochemistry. Physics and chemistry of material science " - Álmaty, - 2021.

Publications. The results of the dissertation were published in 24 printed works, including 4 articles included in the Scopus database, 4 publications were published in the publications recommended by the Committee for Control of Education and Science of the Republic of Kazakhstan, 16 - in the collections of international symposiums and foreign conferences.

Links to research and government programmes.

The topic presented to the defense of the thesis « Development of compositions for shock wave absorption in emergency explosions», performed within the framework of ISTC INTERNATIONAL SCIENCE AND TECHNOLOGY CENTER Project No. #G-2209 Automated System for Protection from Accidental Explosions in Underground Structures, 2016-2019 and Basic Research Programs: «Grant Funding» under the theme: «Obtaining liquid fuels from coal and solid organic waste in the presence of pasteurs».

Volume and structure of work. The dissertation work is presented in 101 pages and includes 60 drawings and 17 tables. The work consists of an introduction, a review of the literature, a description of the objects and methods of research, the results and their discussion, a conclusion and a list of the sources used from 96 names.

The personal contribution of the author consists in setting up and conducting experiments, determining methods of analysis and ways to solve the set practical and theoretical problems, summarizing and interpreting the results obtained, writing articles and reports.