ABSTRACT

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

Amir Zhanibek Amiruly on the topic
"Pyrotechnic compositions for gas generators of destructive impact on concrete structures".

The dissertation is devoted to the development and study of new gas-generating compositions based on ammonium nitrate and ammonium perchlorate with additives of combustible magnesium, polyethylene, polyethylene terephthalate.

Thermodynamic calculations of combustion parameters of gas-generating compositions were carried out to determine the optimal content of initial components of pyrotechnic gas-generating compositions. Experimental studies of combustion processes were carried out and formulations of gas-generating compositions based on ammonium nitrate and ammonium perchlorate with subsonic combustion speed and operability of combustion products (RT) were developed. Field tests of the developed gas-generating compositions were carried out to determine the possibility of their use in practice.

The first chapter is devoted to a literary review, which examines the current state and prospects for the use of high-energy compositions, the formulations of various gas generators, as well as the use of pyrocomposes for the destruction of concrete among dense mountain buildings and block stone mining.

The second chapter contains research methodologies, including the use of TDS programs for calculations, as well as physicochemical and technical research methods, methods for determining temperatures, pressure and speed.

In the third chapter, gas generator compositions based on ammonium nitrate were developed, used to break down concrete structures of medium strength. TV, HP are solved - problems by the method of extremum of characteristic functions, laid down in the TDS software complex to determine the optimal number of initial components of the composition.

In the fourth chapter, gas-generating compositions based on ammonium perchlorate were developed, used to destroy strong concrete structures. It was shown by TG-DSC that PE is well oxidized at 279.9 °C, 372.3 °C AN and APC, which indicates the possibility of their use in steam. The combustion products of the compositions were identified by XRD and gas chromatography.

In the fifth chapter, the physical and mechanical characteristics for compositions based on AN, APC were studied. It has been established that in case of forward and sliding impacts on test samples, their heating temperature does not reach the ignition temperature, the design safe impact energy for the developed systems was, not less than 9.8 J, which confirms the insufficiency of the impact energy equal to 49 J. All samples based on AN, APC after exposure to temperatures from -40 to + 40 C° confirmed their performance for two hours.

In the sixth chapter, compositions based on AN, APC were tested for efficiency in the ECCEM landfill (Ust-Kamenogorsk). It has been proven that these compositions can be used to destroy concrete structures of different strength in harsh climatic conditions up to -40 C°. Theoretically and experimentally, it was confirmed that poisonous gases such as carbon monoxide, nitrogen oxides, chlorine have maximum permissible concentrations.

Relevance of the research topic.

Concrete and reinforced concrete are widely used in all countries for the construction of a wide variety of objects. In the near future, these materials will remain the most used in all areas of construction. It often becomes necessary to dismantle reinforced concrete structures. Now, the most common method of destruction of reinforced concrete structures is crushing using hammers and jackhammers. There are also alternative methods of destruction, such as detonation of an explosive charge, electric pulse destruction, shock destruction and a number of others. But there are times when traditional concrete breaking technologies are not applicable or too laborious. For example, work in the premises of the existing production, in the area of dense development, in basements and buried premises, in the vicinity of cables, water ducts, heating networks and other communications.

The accumulated experimental data make it possible to identify methods by which it is possible to influence not only the groups of combustion characteristics of the IR, but also individual properties. Despite the importance of this issue, to date, the regularities of the influence of the concentration and properties of components on the complex of characteristics of multicomponent PS and their combustion products have not been studied.

In this regard, the scientific and technical justification and development of new gas-generating compositions by studying the physicochemical properties of the components is an urgent task.

Purpose of the research:

The purpose of this dissertation work is to develop and study new, effective gas-generating pyrotechnic compositions based on different oxidizers, operating in critical climatic conditions, which can be used in the destruction of concrete structures, block stone mining, with minimizing unit costs and improving labor safety.

Research objectives:

1. Execution of thermodynamic modeling using the computer code of the TDS program of combustion parameters of gas-generating compositions to determine the optimal content of the initial components;
2. Experimental studies of combustion processes of gas-generating compositions based on ammonium nitrate and ammonium perchlorate with subsonic combustion rate and operability;
3. Examine the physical and mechanical characteristics of pyrotechnic systems based on ammonium nitrate, ammonium perchlorate;
4. Test the developed gas-generating compositions at the ECCEM test site.

Research methods

When solving the tasks necessary to achieve the set goals, the following research methods were used: thermodynamic calculation using the TDS program, thermogravimetric analysis, differential scanning calorimetry, linear method for determining the combustion rate, method for determining the ignition delay time, 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:

1. Development of energy-intensive compositions based on ammonium nitrate, destroying concrete blocks of medium strength. Composition №1: NH_4NO_3 - 70%, PE - 20%, Mg - 10%, characterized by combustion temperature 1890 °C, combustion speed 1.4 mm/s, operability 660 kJ/kg, Q_{cv} = 2740 kJ;

2. Thermodynamic modeling and results of experiments of combustion parameters for a pyrotechnic system based on ammonium perchlorate, destroying strong concrete blocks. Composition №2: NH_4ClO_4 - 85%, PE - 10%, Mg - 5%, characterized by a burning temperature of 2425 °C, a burning speed of 1.6 mm/s, a working capacity of 1024 kJ/kg, Q_{cv} = 3438 kJ;

3. Experiments for failure/explosion at direct (not less than 100 mm, not more than 500 mm) and sliding impact (not less than 200 MPa, not more than 680 MPa) systems based on ammonium nitrate, ammonium perchlorate. Thermal stability studies showed trouble-free performance in critical climatic conditions in the temperature range - 40 °C - + 40 °C.

4. The results of testing pilot tests at the ECCEM test site (Ust-Kamenogorsk) indicate the effectiveness of compositions based on AN and APC. The operability of compositions based on AN, APC, which can be used to destroy concrete structures, mining block stone, has been experimentally proven.

The scientific novelty of the results of the dissertation consists in the development of new pyrotechnic gas-generating compositions, which are characterized by the following aspects:

1. The development of new recipes for gas-generating compositions based on ammonium nitrate (NH_4NO_3-70%, PE-20%, Mg-10%), ammonium perchlorate (NH_4ClO_4-85%, PE-10%, Mg-5%) with a high combustion rate of 1.4-1.6 mm/s and a temperature of 1890-2425 °C;

2. Theoretical justification for increasing the efficiency of destruction of concrete structures with the help of pyrotechnic compositions is given;

3. Modification of classical gas generators with magnesium, with the study of the influence of prescription factors on energy characteristics;

4. Parameters of sensitivity of compositions based on AN, APC on direct and sliding impact with energy of at least 9.8 J were experimentally determined, which proves occupational safety. Thermally stable operating under critical climatic conditions in the temperature range -40 ° C - + 40 ° C;

5. The possibility of using energy-intensive compositions for the destruction of concrete is justified and mathematical modeling of the combustion parameters of the compositions based on AN, APC is given.

These gas generating compositions can be used not only for the destruction of artificial objects, but also for the extraction of block stone in critical climatic conditions.

Practical significance of the results obtained

The calculated and experimental data on determining the influence of the physicochemical properties of the components on the main characteristics of the PS can be used to develop new and increase the efficiency of existing pyrotechnic compositions intended for use as a working medium in devices for active action on artificial concrete structures.

When using low-density gas-generating compositions, the formation of harmful, poisonous gases, the brisant effect of the explosion, expressed in the formation of seismic, shock air waves and the dispersion of individual block fragments, is completely excluded. In this regard, in this work, gas-generating compositions based on ammonium nitrate and ammonium perchlorate were developed, operating in a combustion mode and practically excluding the brisant effect of an explosion manifested in the form of SAW and SW, as well as in the form of a scattering of small fragments.

The developed gas generator compositions have high energy characteristics and can be used to destroy artificial objects and to extract block stone. An integrated development of technologies for the production of gas-generating compositions, as well as a proven scientific and technological base for solving a number of practical problems for target consumers, was obtained.

Work testing

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

1. V International Scientific Conference "Laser, Plasma Research and Technology - LapLas 2019" (Moscow, Russia, February 12-15, 2019);
2. IV International Scientific Conference "Chemical Physics and Nanomaterials" (Almaty, Kazakhstan, April 19, 2019);
3. IV International Scientific Conference "Chemical Problems of Our Time" (Donetsk, Ukraine, May 19-21, 2020);
4. VI International Scientific Conference "Laser, Plasma Research and Technology - LapLas 2020" (Moscow, Russia, February 11-14, 2020);
5. VII International Scientific Conference "Laser, Plasma Research and Technology - LapLas 2021" (Moscow, Russia, March 23-26, 2021);
6. V International Scientific Conference "Chemical Problems of Modernity" (Donetsk, Ukraine, May 18-20, 2021);
7. XIII International Symposium "Chemical Physics, Materials Science, Nanomaterials" (December 20-21, 2022, Almaty, Kazakhstan).

Publications. The results of the dissertation were published in 23 printed works, including 8 articles included in the Scopus database, 5 publications were published in the publications recommended by the Committee for Control of Education and Science of the Republic of Kazakhstan, 10 - in the collections of international symposiums and foreign conferences.

Volume and structure of work. The dissertation work is presented in 102 pages and includes 58 drawings and 19 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 108 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.