Effect of Physical and Chemical Properties of Explosive Materials on the Conditions of their Use

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Keywords: explosive ordnance; explosive materials; physical and chemical properties; molecule structure; oxidizer; detonation propagation velocity.

Abstract. The components of the most common explosive ordnance in Eastern Europe have been analysed. The most dangerous explosive materials that rescuers may encounter when disposing explosive ordnance and clearing territories from mines have been identified. Such hazardous materials include tetryl, texogen, trinitrotoluolol, mercury fulminate, lead azide, lead trinitroresorcinate. An analysis of the chemical structure and physical and chemical properties of such materials has been carried out. It has been established that explosive materials can be divided into two classes with similar values based on such parameters as detonation velocity, volume of explosion products, and explosion heat. It has been established that the chemical structure of their molecules corresponds to the said two classes of physical and chemical properties. The first class includes materials based on hydrocarbons, the second includes materials based on heavy metals. It has been established that the specific volume values for the second class materials increase significantly, and exceed the indicators for the first class materials. This is due to the difference in the density of such materials by 2 to 4 times. The established features of the physical and chemical and explosive parameters of explosive materials can be used in the development of standard operating procedures and plans of actions of rescuers in order to increase the safety of handling the explosive ordnance.

Introduction

The latest achievements of scientific and technical progress in the defence industrial complex are leading to an increase in the variety and lethality of weapons. Mine weapons have one of the oldest histories. A few centuries ago, man first began to use the powder energy of explosion. It is used for killing and maiming manpower, damage and subsequent disabling of equipment, by impact of explosion and shrapnel. As practice shows, during military conflicts, mine weapons carry losses not only for military units, but also for the civilians, among whom a significant part is children.

As a result of the full-scale invasion of the Russian Federation into Ukraine, almost half of the territory of our country was potentially contaminated with mines and explosive ordnance (EO). The area of the territory that needs to be cleared from EO is 185,000 square kilometres. Operational demining of roads and settlements will be carried out throughout the year, however, complete demining will take a long time. An analysis of the experience of using EO in local wars and armed conflicts shows that the use of mines has the following characteristics: instead of long minefields, small groups of mines and even individual mines are usually placed; mine groups and individual mines are most often placed unsystematically and are not recorded in documents, placement of controlled mines becomes more widespread; minefields; a huge number of improvised and home-made mines, detonators and explosives are used, which are dangerous in making and use for those who make them. In such cases, the demining of EO requires knowledge and analysis of the technical component of the explosive device and the chemical properties of explosive materials.

Problem formulation

Most of the world's countries are engaged in the development of their own weapons based on explosive ordnance. Furthermore, various terrorist organizations are involved in the illegal manufacture of explosive devices. As a result, there is a wide variety of explosive ordnance with different systems of delivery, initiation, and explosion in the world. This leads to significant difficulties in their demining and disposal. In order to simplify the work of EOD specialists and increase their safety, there is a need to establish general laws and polish general safety rules with explosive ordnance. Obviously, the main source of danger of explosive ordnance is the explosive materials that make up its basis [33]. Operating on the premise that an explosion is a rapid flow of a chemical reaction, thus safety rules with explosive materials are determined primarily by their physical and chemical properties.

Analysis of publications

Ensuring the safety of various facilities is currently of particular importance for any of the states in the world. This is related to resolving the common issue of sustainable development of states and world civilization as a whole [25, 29]. At the current stage, all advanced countries are developing technologies to improve the safety of rescuers [1, 23, 27]. The main indicator of safety is the assessment of the risk of a person in an aggressive environment [2, 21]. The most effective approach to ensuring safety is early prediction of the consequences of an emergency situation [3, 19] and the nature of the danger that the rescuer may face [4, 26]. The blow-out liquidation leads to involve a big financial resources andlots of people [24]. However, despite significant technical progress, demining remains one of the most dangerous spheres for rescuers [18]. Anti-personnel landmines are one of the main causes of civilian casualties in conflict-affected areas and a significant obstacle to post-war reconstruction [5]. Despite twenty-first century technological advances achieved by Western militaries in demining and removing improvised explosive devices, humanitarian demining largely relies on mid-twentieth century technologies [6]. No single technology can detect all types of landmines under all environmental conditions, and there is a need to develop multi-sensor detection systems to overcome the limitations of each sensor.

Apart from the development of preventive measures to avoid an explosion, the safety of handling explosive substances is also actively investigated [7, 30]. In order to increase the safety of the operations of rescuers, new and safer plans of actions of rescuers when handling explosive ordnance are being developed. For these reasons, the structural features and principles of action of all ammunition and explosive ordnance are thoroughly studied. Based on the fact that a large number of various explosive ordnances have been developed and used in the field in recent years, rescuers need to have an extensive knowledge base. In such cases, the principle of similarity is applied and explosive ordnance is considered by class according to the similar parameters [8]. However, despite the wide variety of structural features of ammunition, the main danger is the explosive materials themselves [9]. Yet all the actions of rescuers are focused precisely on preventing the initiation of an explosive reaction of such materials.

The course of the explosion is a rapid oxidation reaction. However, unlike the same oxidation reaction during combustion, a multiple increase in the reaction velocity is achieved by the presence of an oxidizer and an oxidizing substance in the structure of the explosive material molecule [10]. Recently, substances with nitrogen atoms as an oxidizer have become widespread among explosive materials. This is explained by the high oxidizing activity of nitrogen. As a substance that oxydizes in the structure of modern explosive materials, hydrocarbon-containing and heavy metal-based substances are found [28]. The chemical structure of the explosive material define its physical and chemical properties [11, 22]. When studying the physical and chemical properties of materials, they are tested for the effects of fire [12, 32], electromagnetic interference [13], radiation [14, 20], etc. It is the physical and chemical characteristics of materials that determine their explosive properties [31]. Therefore, in order to increase the safety of operations of rescuers during the disposal and clearing of the territory from explosive ordnance, as well as the development of new safety rules for handling such ordnance, it is necessary to establish both the

when handling them. Among the most common and dangerous materials, the explosive properties of tetryl, texogen, trinitrotoluene, mercury fulminate, lead azide, and lead trinitroresorcinate have been analysed. When analysing the physical and chemical properties of such materials, it has been established that the greatest danger is posed by hexogen, as it has the highest detonation velocity: 8640 m/s, the volume of explosion products: 908 L/kg, a relatively high heat of explosion: 5.45 MJ/ kg and a low flash point: 500 K. It has been established that explosive materials are divided into two characteristic classes according to their physical and chemical properties. These classes clearly correspond to the structure of the molecules of such substances. Namely, explosive materials based on hydrocarbon oxidizing components belong to the first class, and materials containing heavy metals - to the second, respectively. It has been determined that since the density of materials of the second class is 2 to 4 times greater than the density of materials of the first class, the specific volumetric values of the explosive parameters have the opposite relationship. Therefore, this fact must be taken into account when developing safe algorithms for handling such materials.

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