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PYROTECHNIC SAFETY IN THE PROCESS OF DEMILITARIZATION OF EXPLOSIVE ORDNANCE FROM THE ASPECT OF APPLICATION OF NEW TECHNOLOGIES

Abstract: *The application of new technologies in result of improving the pyrotechnic safety system, represents one of the priorities in the field of demilitarization of the EO. The conventional demilitarization procedures are partially or does not meet the prescribed standards at all in the field of pyrotechnic safety systems. The use of water-based techniques for the purpose of projectile delaboration directly influences the improvement of the pyrotechnic safety system, as well as the reduction of emissions of harmful and toxic chemical compounds into the working environment. The paper analyzes and research the possibility of improving the pyrotechnic safety system using abrasive waterjet and washout waterjet technology. Current research and conducted experiments show a wide area for the implementation of technology for the needs of projectile delaboration.*
Keywords:*Pyrotechnic safety, explosive ordnance, new technologies, abrasive waterjet*

1. Introduction

The explosive ordnance (EO) is a mass production item whose main characteristic is the presence of one or more explosive substances (ES) or some other dangerous substance (white phosphorus, radioactive substances, chemical poisons) (Assia, 2015). In a wider sense, EO includes all previous operations and processes that have a product that is used for military purposes for the final product. In order to ensure that the process of production, storage, handling, manipulation, maintenance or operation is ensured from adverse effects, it is necessary to define and correctly set up the pyrotechnic safety system (PSS). PSS is a set of organizational and technical-technological measures and procedures aimed at minimizing the possibility of occurrence and possible harmful consequences (Milosavljevic, 2013a).In order to ensure the system, in spite of defining and setting up the PSS it is necessary to know the process and critical characteristics of the ES:

- sensitivity of ES to the effects of external pulses (mechanical and thermal),
- mechanical and chemical stability of ES,
- the conditions for passing the combustion into a detonation,
- ignition temperature and self-ignition temperature,
- critical diameter, thickness and mass,
- toxicity,
- volatility and durability in the environment.

When all the above facts are considered, EO, as a whole, represents a complex technical

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system consisting of a series of subsystems. EO primarily represents a set of explosive, toxic, radioactive and other materials, but also of great importance are electronic, mechanical and other chemical-technological systems. First of all, there is a possibility that improper handling through these systems leads to the initiation and the effects of EO at an unwanted time (Jeremic et al., 2008).

The process of demilitarization (delaboration or destruction) is an integral part of the life cycle of each EO (inverse from the process of the laboratory). This process is in itself very complex and represents a high-risk operation (Djuric et al., 2018). Demilitarization of EO involves the translation of EO from a state ready for action at the target, into a state in which this asset can no longer perform the main function for which it is intended (Bogdanov, 2015, p. 13). In the paper (Munitions Safety Information Analysis, 2006), an overview of the technologies of work and destruction is given. Although from the aspect of security and ecology are completely unacceptable, they are still the most common methods:

- open detonation,
- open burning.

In order to replace these methods, recent years of research are based on the development and implementation of new technologies in the function of demilitarization EO. It is primarily focused on procedures that are safer for the work environment and environment overall, as well as procedures that are environmentally friendly. Also, the application of new methods aims to conquer the technology of delaboration of product, that has been so far solely destroyed in the open space (EO large caliber, unexploded EO ...) or permanently dumped.

The paper discusses the improvement of the pyrotechnic safety system of the EO operationfrom the aspect of the application of water jet technology.

2. Pyrotechnic safety system in the Explosive ordnance delaboration

When working with EO, there are a number of operations and phases that require defining the pyrotechnic safety system, risk assessment and including standards that accompany the entire process (Milosavljevic, 2013b). The term pyrotechnic safety refers to the lack of the possibility of the formation of a fire and explosion of EO or explosive materials in their direct or indirect manipulation (Jeremic et al., 2008). PSS is an integrated set of organizational and technical-technological procedures and measures aimed at minimizing the occurrence of adverse effects from the effects of explosion or fire (Assia, 2015).

In order to successfully manage the risk, it is necessary to build and maintain an integrated management system within which the PSS will be developed to suit the operations and needs of a particular unit. In the paper (Milosavljevic, 2013b) the concept of risk management according to ISO 31000: 2009 was explained and defined. Also, as an integral part of the work (Milosavljevic, 2013b), the International Technical Guide IATG 02.10 has been elaborated which focuses on the risk management process in the field of work with EO.

Pyrotechnic safety measures include the following entities (Assia, 2015):

- risk identification,
- risk analysis,
- risk assessment.

In the risk assessment, the organizational unit should identify, analyze and evaluate all the critical points in the system, which are classified as very dangerous according to the classification of risks (Karovic & Komazec 2010; Kekovic, Glisic & Komazec 2010).

Pyrotechnic safety measures include the following entities (Assia, 2015):

1. general organizational measures,
2. preventive measures,
3. personal measures,
4. building-technical measures and spatial planning measures,
5. equipping and preparedness measures,
6. responses to fire and explosion.

The process of the EO delaboration , as one of the life cycle phases, is considered a high-risk operation. Classical methods of work, constantly expose operators to the harmful effects of carcinogens and toxic substances during the process (Jeremic, 2012). Although operations are considered risky by conventional procedures, they are still the most prevalent, especially in the territory of the Republic of Serbia (Jeremic, 2012). The cause of this situation is primarily obsolete technology, insufficient information and ignorance of current technologies. In order to improve PSS, it is necessary to look at the whole of pyrotechnic safety measures. By developing and implementing new technologies in the function of projectile deployment, there is a possibility of improving the system primarily in the part of preventive and personal measures (Assia, 2015; Milosavljevic, 2013a). The review of literature and the analysis of the occurrence of harmful events it is concluded that in most cases the main factor is the human factor. On the other hand, the application of new technologies enables the increase of the degree of automation of the process, which directly reduces the dependence of the human factor's error (Jeremic, 2012). Current research (Munitions Safety Information Analysis, 2006; RIGHTTRAC Technology Demonstration Project, 2010) shows the widespread use of new technologies, above all non-conventional metal treatment processes. In the works (Hloch et al., 2011; Kmec et al., 2010) the possibility of using the abrasive water jet for the needs of projectile delaboration is shown. As part of the research on application possibilities (Djuric et al., 2018), experimental tests for the calibration of the missile shells 100 mm and 105 mm are analyzed. Existing technology involves the deployment of these missiles to conventional explosive melting processes, which, by the action of harmful chemical compounds, directly impairs the health of the operator, as well as the atmosphere and environment in which the compounds are released (Jeremic, 2012). By developing and applying Waterjet technology for the needs of the EO delaboration process, as one of the technologies being tested, it directly affects the reduction of risk and the improvement of PSS in units 1,2 and 3.

3. Application of new technologies in the Explosive ordnance

The application of new technologies in the field of EO delaboration should primarily provide a safer, more reliable and environmentally friendly process. The most common technologies in the field of non-conventional post processing are technologies based on water jet processing. Primarily related to processing (Munitions Safety Information Analysis, 2006; RIGHTTRAC Technology Demonstration Project, 2010):

- abrasive waterjet technology and
- washout waterjet technology.

The abrasive water jet processing technology (AWJ) requires a smaller number of participants to perform the process, thereby reducing the influence of the human factor. In addition, the process ensures a high level of productivity, by making it possible to process more pieces simultaneously, whether the same or different caliber.

In relation to classical procedures, in which the possibility of working depends on explosive filling, where it is necessary that the ES mixture is permeable to the part of the TNT, in AWJ it is possible to cut and destroy the projectile shaft which can not be worked out by conventional methods, but

only destroyed (figure 1). By conventional procedures, EM is working on heating the explosives to excess liquid, which greatly relieves harmful chemical compounds. The use of AWJ is not necessary, or only partial heating of explosives is necessary, which depends on the method of the previous procedure of the laboratory.

Figure 1. Contamination during the open detonation

The investigation of the possibility of cutting the missile shaft shown in the paper (Djuric et al., 2018) gives the possibility of developing the technology and a significant improvement in the process of delaboration, which directly affects the level of safety (figure 2). Using AWJ technology, preventive effects on risk reduction and improves PSS overall.

Figure 2. Application AWJ technology in the process of shellcutting

Also, in addition to stationary plants, it is possible to develop mobile workstations for the destruction of unexploded EO, which according to the classification belong to the group of the most dangerous EO items.

The application of Washout waterjet technology (WJW) is possible with screws where the explosive is labored by a pressing method. The action of water vapor on explosive filling results in the destruction of explosives, with the explosive removed from the shell (figure 3). With the application of WJW technology, ES is removed more completely, in contrast to the melting process where the EM remains glued to the walls of the shell.

Figure 3. Application WJW of projectiledelaboration process

In the WJW procedure, the basic geometry of the projectile is not disturbed, and there is no rupture of the shell, which enables the reuse of the shell in the process of the laboratory (Borkowski, Borkowski& Wozniak, 2008).

4. Conclusion

The application of new water jet technologies is a special challenge in the field of demilitarization EO. It primarily improves the pyrotechnic safety system by reducing human engagement, which directly reduces the direct exposure of the operator to toxic substances. On the other hand, process automation and universality in terms of a greater choice of products give significantly greater opportunities when productivity is concerned. There is no need to make special tools and accessories to allow for the work of each caliber in particular. EO, which due

to the limitations of classical procedures destroyed by detonation or burning outdoors, or permanently deposited, can now be processed and reused using AWJ or WJW. By destroying , in spite to extremely high levels of pollution and high risk, explosive charges are being destroyed that can be regenerated and reused using the AWJ and WJW procedures. AWJ and WJW technologies for civilian needs and standard purposes are sufficiently developed with all known parameters, however, for the needs of project planning, it is necessary to adapt the technology and align with the restrictions dictating the specificity of explosive substances.

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