1.Stefan ĐURIĆ, 2.Bogdan NEDIĆ, 3.Slobodan MALBAŠIĆ, 4.Jelena BARALIĆ

APPLICATION OF NEW TECHNOLOGIES FOR DEMILITARIZATION ORDONANCE IN ORDER TO PROTECT ENVIRONMENT

1,2.Faculty of Engineering University of Kragujevac, Sestre Janjić 6, 34000 Kragujevac, SERBIA
3.Ministry of Defence Republic of Serbia, Bircaninova 5, 11 000 Belgrade, SERBIA
4.Faculty of Technical Science University of Kragujevac, Svetog Save 65, 32000 Čačak, SERBIA

Abstract: Demilitarization of the explosive ordnance using the conventional methods, which are most common, results in significant environmental pollution. In the demilitarization process and destroying explosive ordnance, toxic particles of heavy metals and chemical compounds of explosive substances from ordnance that are being processed, are being released in the environment. Current research shows that conventional methods pollute up to ten times more than modern methods of destruction. The paper discusses the application of unconventional processing methods in order to develop new technologies for the explosive ordnance disposal (EOD) in order to improve the environmental aspects of this process. Experimental tests have shown the positive results of abrasive water jet application in the process of cutting the projectile shell, which, in addition to reducing the harmful effects on the environment, raises the level of safety and productivity of the entire process of work.
Keywords: demilitarization, contamination, environment, unconventional methods, abrasive water jet

INTRODUCTION

Demilitarization of explosive ordnance (EO) is a complex process that includes a series of operations that are divided into several phases. The EO can be delaborated or destroyed for a number of reasons, the most frequent ones being the decommissioning of outdated items, then the EO damaged during transportation, natural disasters, poor storage conditions, etc. Special emphasis is placed on ordnance articles that are destroyed that have previously suffered severe damage due to incidents or accidents (unexploded ordnance). These resources in the given situations are most often destroyed on the spot as they are caught [1].

The ordnance demilitarization process represents the process of translating ordnance into the state in which asset can no longer perform its basic function for which it is intended [2]. During the life cycle of ordnance, complex physical–chemical reactions occur within the device, which increases the risk of unintentional initiation and the occurrence of damage [2, 3]. The demilitarization process is an integral part of the ordnance lifecycle, which aims to include this requirement as a basic requirement at an early stage of development [4].

The STANAG 4518 standard defines that during its development, ordnance is to envisage its delaboration process [5]. Although this standard provides guidance, they do not, however, include everything necessary for the demilitarization process. Considering the demilitarization process in the development phase, ordnance should provide [6]:

- easy disassembly of subassemblies and elements of ordnance,
- easy access and removal of EM,
- processed materials and components can be reused,
- minimizing the use of specialized tools,
- process automation and reduced human resources.

After the events of the 1990s, especially after the NATO bombing in 1999, a large number of ordnance remained to be destroyed on the territory of the Republic of Serbia. These EO are very expensive, dangerous and, on the other hand, useless to store, which necessitates their demilitarization. In addition to solving its own problems with the large number of ordnance, there is room and ability to solve the problem of explosive ordnance on a global level. With the application of new technologies, harmonized with European regulations and legal regulations, it is possible to position itself in the market as a leader in the process of EOD.

The paper presents new technologies in the field of nonconventional processing methods, with a special focus on the application of the material cutting method using the abrasive water jet.

ECOLOGICAL ASPECTS OF ORDNANCE DEMILITARIZATION BY THE APPLICATION OF CLASSICAL METHODS

The classic demilitarization procedures of EO in practice are still the most common, regardless of the large number of limiting factors regarding legal regulations. The focus is on the safety of people and the work environment, which is addressed by applying various preventive methods of protection. Note, that danger lasts directly during the preparation of the process, during the duration of the process, and a certain time interval after the demilitarization process. Second, but considerably more harmful, bearing in mind the lasting consequences are the

environmental aspects of the demilitarization process [2, 6]. The classic methods of the EO demilitarization are divided:
1. open detonation,
2. open burning,
3. detonation in the detonation chamber,
4. contained burn,
5. permanent disposal of EO.

The way of selecting the method to be applied to the demilitarization process depends on several EO parameters:
- physical condition of EO,
- amount of EO,
- legislation and norms,
- available capacities and resources,
- technological options and capacities.

Classical methods such as open detonation and open burning are applied in cases where there is no available technology for the ordnance operation in some other way (Figure 1). These methods are completely unacceptable because they pollute the environment and leave lasting consequences. The environment is contaminated, heavy metals are released, which flow through the soil into submersible water systems or are released into an atmosphere where they can no longer be controlled [2, 7].

Figure 1 Contamination of the environment during the processing EO

Chemical elements such as Pb, Sb, Ba and toxic gases found in combustion products such as hydrochloric, carbon monoxide, nitrogen monoxide, nitrogen dioxide and hydrogen cyanide are easily get in and retain in soil and underground waters [2]. Table 1 shows the emission of toxic gases through the equivalent NO_2 that pollute the air in the demilitarization process.

Table 1. Emission of the particles that pollute air expressed through NO_2 equivalent

Demilitarization method	Process emissions (gram NEQ per kg MEM)
Open burning	285
Open detonation	141
Closed detonation	14
Rotary clin	25

Based on the data presented in Table 1, none of the listed methods meets the requirements of the European Environmental Standards [8].

The paper [2] provides an overview and analysis of the impact of ordnance hazardous ingredients on the environment and on human health. The development of new demilitarization technologies is an absolute priority in terms of research, in order to improve the process, from the aspect of protection, safety and productivity, and enable further demilitarization of the remaining and newly produced ordnance [7].

APPLICATION OF NEW TECHNOLOGIES IN THE DEPARTMENT OF DEMILITARIZATION ORDNANCE

In the process of implementing new technologies, priority is to decreases the level of pollution and release of toxic substances into the environment during the EO demilitarization process. Methods on which a large number of research and experimental investigations are carried out are [6, 9]:
- projectile delaboration using Abrasive Water JET (AWJ) technology,
- projectile delaboration using Water Jet Washout (WJW) technology.

The use of AWJ technology is used in cases of complete EO processing. The technology is based on the cutting of the missile shell transversely in relation to the axis of rotation of the projectile (Figure 2a). In the process of delaboration, there is a permanent disturbance of the geometry of the projectile shell and waste in the form of steel is used in the recycling process as a secondary raw material [7].

Figure 2. Delaboration of projectile by applying AWJ technology

In order to reduce the risk, the process can be entirely underwater. Although there is no thermal change in the structure of the material in the cutting process, the friction of the particles of the explosives can lead to the self–initiation process, which is why it is desirable to process the cutting process in water (Figure 2b). In this way, the level of risk and the possibility of self–initiation process are reduced.

After cutting the shell, the next phase involves the removal of explosive filling from the casing, which can be further recycled and reused in the process of the laboratory. AWJ technology also enables the operation of large–scale caliber missiles (Figure 3a), as well as the deployment of rocket engines (Figure 3b), which is not possible with conventional methods.

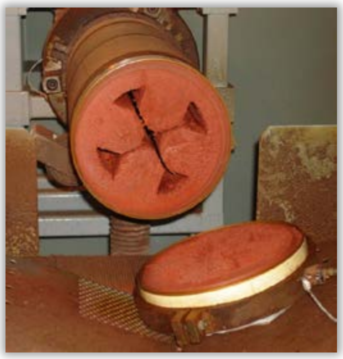

Figure 3. Delaboration of rocket engines and high caliber projectile by applying AWJ technology

Delaboration of projectile using WJW technology is based on the principle of high–pressure explosive loading (Figure 4). Unlike AWJ technology, in the WJW process there is no physical destruction of the missile shell. In this way, it is possible to re–use the missile shell.

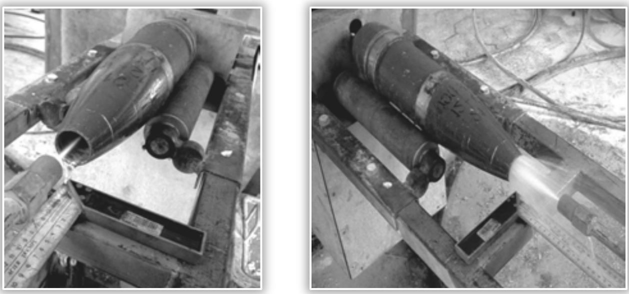

Figure 4. Delaboration of projectile by applying WJW technology

The water used in the delaboration process (AWJ, WJW) during the process is contaminated, but is filtered in the re–process. At the end of the elaboration process, the water is permanently disposed of and treated as wastewater [6].

Laboratory for Cutting metal and tribology at the Faculty of Engineering Sciences in Kragujevac, in cooperation with The Technical Overhaul Institute Kragujevac and The Technical Overhaul Institute Cacak, carried out experimental tests of the process of cutting the projectiles of the caliber 100 and 105 mm.

Figure 5 Display of the 100 mm caliber projectiles when cutting using AWJ

The process of cutting the projectile shell proceeded continuously, with the sample fixed to the work table, while the nozzle was translatrically moving without changing the height of the nozzle in relation to the work table (Figure 5). In the paper [7] results are shown, the cutting parameters and the entire process are analyzed, which determines the possibility of using AWJ technology in the EOD.

CONCLUSION

The paper presents new technologies in the field of nonconventional metal treatment processes. The implementation and application of these technologies in the EO process of delaboration should lead to a significant improvement in the environmental aspects of the EO demilitarization process and partially or completely replace the classical procedures. Classical practices are, from the ecological point of view, completely unacceptable, and in addition they are economically unsuitable, as are high–risk processes. Using AWJ and WJW technology, a significantly larger selection is provided and it extends the ability to delaborate EO of different types and calibers. In this way, beside environmental aspects, efficiency in terms of recycling and reengineering of materials is achieved. Materials and procedures for projectile casing or explosive mixtures and their laboratory technology are one of the most technologically demanding processes. With the application of new technology of delaboration, with overhaul and recycling, the lifetime of expensive elements that are an integral part of the EO system is prolonged and enables them to be reused.

Acknowledgement
This publication was also supported by the Ministry of Education, Science and Technological Development of Serbia, project TR35034 "The research of modern non–

conventional technologies application in manufacturing companies with the aim of increasing efficiency of use, product quality, reduce of costs and save energy and materials".

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

REFERENCES

[1] Bogdanov, J. (2015) Poznavanje ubojnih sredstava, 1st. edition. Medija centar „Odbrana“.
[2] Jeremić, R. (2012) Ekološki aspekti procesa demilitarizacije i uništavanja ubojnih sredstava. Vojnotehnički glasnik, vol. 60, no. 1, pp. 284–298.
[3] Alverbro, A., Björklund, A., Finnveden, G., Hochschorner, E., Hägvall, J (2009) A life cycle assessment of destruction of ammunition, Journal of Hazardous Materials, vol. 170, no. 2–3, pp. 1101–1109.
[4] Mescavage, G (2009). Demilitarization as a systems engineering requirement. 44th Annual Gun & Missile Systems Conference & Exhibition, 6–9 April 2009, Kansas City, USA.
[5] NATO Standardization agensy (NSA), NATO Standardization agreement: Safe disposal of munitions, design principles and requirements, and safety assessment, STANAG 4518, 2001.
[6] Poulin, I. (2010) Literature review on demilitarization of munitions, Document prepared for the RIGHTTAC Technology Demonstration Project, Defence Research and Development Canada.
[7] Đurić, S., Nedić, B., Baralić, J., Bogdanov, J., Miljković, A. (2018) Researching the possibility of applying abrasive waterjet in projectile disassembly process, 8th International Scientific Conference on Defensive Technologies OTEH 2018 Conference Proceedings, pp. 200–204.
[8] Duijm, N.J., Markert, F (2002) Assessment of technologies for disposing explosive waste, Journal of Hazardous Materials, vol. 90, no. 1, pp. 137–153.
[9] Wilkinson, J., Watt, D. (2006) Review of demilitarization and disposal techniques for munitions and related materials, Document prepared for the MSIAC member nations, Munitions Safety Information Analysis Center.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067–3809