1951-2021 SMEITS

DOIEE

IAUS ИАУС

PRIVREDNA KOMORA SRBIJE 1857

Република Србија
МИНИСТАРСТВО НАУКЕ, ТЕХНОЛОШКОГ РАЗВОЈА И ИНОВАЦИЈА

11th International Conference on Renewable Electrical Power Sources

PROCEEDINGS

Editor Dr Milica Vlahović

Belgrade, November 02-03, 2023

PROCEEDINGS

11th International Conference on Renewable Electrical Power Sources

MKOIEE/ICREPS

1951-2021 SMEITS

DOIEE

2023

PROCEEDINGS
11th International Conference
on Renewable Electrical Power Sources

Chamber of Commerce and Industry of Serbia,
Belgrade, November 2 and 3, 2023

Publisher
Union of Mechanical and
Electrotechnical Engineers and
Technicians of Serbia (SMEITS)
Society for Renewable Electrical
Power Sources
Kneza Miloša str. 7a/II,
11000 Beograd

President to the Society
for Renewable Electrical
Power Sources
within the SMEITS
Prof. dr Zoran Lazarević

Editor
Dr Milica Vlahović

Tiraž
50 primeraka

CD umnožava
MT-KOMEX doo, Beograd

ISBN
978-86-85535-16-1

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

MEĐUNARODNA konferencija o obnovljivim izvorima električne energije (11 ; 2023 ; Beograd)
Zbornik radova pisanih za 11. Međunarodnu konferenciju o obnovljivim izvorima električne energije [Elektronski izvor]: [Beograd, 2. i 3. novembar 2023.] / [urednik Milica Vlahović] = Proceedings / 11th International Conference on Renewable Electrical Power Sources : [Belgrade, October 2 and 3, 2023] ; [editor Milica Vlahović]. - Beograd : Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije SMEITS, Društvo za obnovljive izvore električne energije = Union of Mechanical and Electrotechnical Engineers and Technicians of Serbia (SMEITS), Society for Renewable Electrical Power Sources, 2023.

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 50. - Bibliografija uz svaki rad.

ISBN 978-86-85535-16-1

a) Енергетски извори - Одрживи развој - Зборници

COBISS.SR-

Organizer

Savez mašinskih i elektrotehničkih
inženjera i tehničara Srbije (SMEITS),
**Društvo za obnovljive izvore
električne energije**

Co-organizer
Institut za arhitekturu i urbanizam Srbije,
Beograd

Privredna komora Srbije,
Beograd

Sponsors

Interplast, Greece

MS Kablovi, Paraćin

Endorsement

MT-KOMEX, Beograd

Održavanje 11. MKOIEE finansijski je pomoglo
Ministarstvo nauke, tehnološkog razvoja i inovacija
Republike Srbije

Република Србија
МИНИСТАРСТВО НАУКЕ,
ТЕХНОЛОШКОГ РАЗВОЈА И ИНОВАЦИЈА

International Scientific Committee

Organizing Committee

FOREWORD

The conditions created by the development of technologies in which modern man lives have led to a complex and paradoxical effect: that by removing obstacles on the way to a more comfortable, simpler, faster and more efficient life and way of working, man also generates numerous misfortunes, attracting dark clouds of threats to the survival of the planet and humanity. The question that concerns and affects all of us - all people, all living beings, systems in which life takes place, large and small, strong and weak - boils down to the problem of the negative impact of man on the environment; this issue invites us to an urgent solution by looking at the causes, proposing solutions, evaluating them, changing approaches and ways of thinking, as well as drawing correct conclusions. Simply put, by adapting nature to one's own needs, man threatens and damages it. That is why, with the joint efforts of all of us, individuals, organizations and states, it is necessary to take all possible measures to immediately prevent the negative effects that are ahead of us.

The importance of renewable sources of electricity, which this international conference focuses on, is noticeable from two angles: the first - it is certain that fossil fuels as a resource will disappear and it is necessary to find alternative sources, the second - the use of renewable energy sources by its essence implies "clean" technology that significantly contributes to reducing CO_2 *emissions and thus mitigating climate change and reducing pollution, while encouraging social and economic development in all spheres of life.*

The 11th International Conference on Renewable Electrical Power Sources is organized by the Society for Renewable Electrical Power Sources (DOIEE) at SMEITS, with co-organizers: The Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS) and the Chamber of Commerce and Industry of Serbia, with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

The registered participants designed their papers according to the given conference topics:
- *Energy sources and energy storage;*
- *Energy efficiency in the context of use of renewable energy sources (RES);*
- *Environment, sustainability and policy;*
- *Applications and services.*

Eminent authors - scientists, teachers, experts in this field from fifteen different countries: Algeria, Belgium, Bosnia and Herzegovina, China, Croatia, Greece, Hungary, India, Portugal, Saudi Arabia, Serbia, Slovenia, Spain, the United Arab Emirates, and Ukraine, contributed to the conference through sixty-nine papers that were reviewed by the Scientific Committee of the Conference, and after the review process were accepted for presentation at the conference and for publication in the proceedings.

At the end of this short message and at the beginning of the proceedings I believe that it can be proudly said that scientists, researchers, policy makers and industry experts gathered in one place, in order to exchange experiences and knowledge with the aim of promoting scientific and professional ideas and results of research, technology improvement for the use of RES, promoting the rational use of electricity, affirming and proposing inventive solutions in the field of sustainable sources of electricity.

Belgrade, *Milica Vlahović*
November 2023

SADRŽAJ / CONTENTS

Aplikacije:

SAGOREVANJE OTPADNOG TERMOBARIČNOG EKSPLOZIVA POD KONTROLISANIM USLOVIMA KAO IZVOR ENERGIJE

COMBUSTION OF WASTE THERMOBARIC EXPLOSIVE UNDER CONTROLLED CONDITIONS AS A SOURCE OF ENERGY

Danica Bajić*, Mirjana Krstović, Mladen Timotijević, Bojana Fidanovski
Military Technical Institute, Belgrade

Ana Alil
University of Belgrade, Institute of Chemistry, Technology and Metallurgy
National Institute of the Republic of Serbia

danica.bajic@mog.gov.rs (*Correspondence)

Apstrakt

Termobarične eksplozivne smeše su u poslednje vreme dosta proučavane zbog specifičnih energetskih efekata, posebno u pogledu toplotnog dejstva tokom faze post-detonacionog sagorevanja. Većina ovih smeša sadrži kao veoma važnu gorivnu komponentu neki metalni prah koji nakon iniciranja sagoreva u kontaktu sa atmosferskim kiseonikom ili oksidatorskom komponentom smeše. Ovaj proces sagorevanja oslobađa veliku količinu toplotne energije, koja je prepoznata kao potencijalni izvor drugih vidova energij ukoliko bi se oslobađala i dalje transformisala pod kontrolisanim uslovima. U ovom istraživanju razmotrena je mogućnost kontrolisanog sagorevanja otpadnog termobaričnog eksploziva kao izvora energije. Analizirane su termobarične smeše koje sadrže prah aluminijuma, magnezijuma i bora. Za izračunavanje parametara njihovog izohorskog i adijabatskog sagorevanja korišćen je softver EXPLO5, za predviđanje potencijalnog toplotnog efekta ovih smeša. Odabrani sastavi su eksperimentalno ispitani metodom kalorimetrije na malim uzorcima kako bi se utvrdio njihov energetski potencijal pri sagorevanju u atmosferi inertnog gasa u kalorimetrijskoj bombi. Dobijeni rezultati podstiču dalje istraživanje mogućih primena ove toplotne energije koja se može osloboditi ne samo u reakciji destruktivne eksplozije, već i kroy sagorevanje u kontrolisanim uslovima, kao kvaternernu reciklažu otpadnih eksploziva - potencijalni izvor toplotne odnosno električne energije.

Ključne reči: *Energija sagorevanja; otpadni termobarični eksplozivi; metalni prahovi; termodinamički kod EXPLO5, toplotna energija*

Abstract

Thermobaric explosive mixtures are recently widely studied due to their specific energetic effects, especially regarding thermal output during the post-detonation combustion phase. Most of these mixtures contain as a very important component some metal powder fuel, which burns in contact with atmosphere oxygen or the oxidant component of the mixture after the initiation. This combustion process releases a large amount of thermal energy, which is recognized as a potential source of other types of energy if it were released and further transformed under controlled conditions. In this research, the possibility of controlled combustion of waste thermobaric explosives as a source of energy was considered. Thermobaric compositions containing aluminium, magnesium and boron powder were analysed. EXPLO5 software was used to calculate parameters of their isochoric and adiabatic combustion, to predict the potential thermal output of these mixtures. The selected compositions were experimentally examined in small samples by the method of calorimetry to determine their energetic potential during combustion in atmosphere of inert gas in a calorimetric bomb. The obtained results encourage further research into the possible applications of this thermal energy, which can be released not only in the reaction of a destructive

explosion, but also by combustion under controlled conditions, as a quaternary recycling of waste explosives - a potential source of heat and electric energy.

Key words: *Combustion energy; waste thermobaric explosives; metal powders; thermodynamic code EXPLO5, heat energy*

1 Introduction

In addition to extensive research of new compositions and new technologies for the production of explosive materials, there is an emerging need to develop techniques for their recycling or safe disposal. Cast cured polymer bonded explosives (PBX) are widely studied and implemented in most modern weapon systems for decades, leading to their stockpilling, which requires finding the best solution for recycling, demilitarization or other proper treatment of hazardous waste, Figure 1. This is important, since there is a risk of long-term air, soil, and water pollution caused by the improper disposal of waste energetic materials due to their hazardous nature and toxicity [1-6]. There are even research studies on eco-friendly, water-soluble binders for PBX compositions, providing the solid ingredients easier to recover and reuse [7].

Among the most produced groups of energetic materials today are cast-cured composite propellants and PBX, due to their lower sensitivity compared to conventional compositions, thermo-mechanical resistance, and safety aspects of their production, handling and storage. However, they certainly have a limited life cycle and they can deteriorate through ageing or become obsolete due to development of new weapons. Therefore, there is a need for new technologies for their safe and inexpensive disposal, or some cost-effective reuse or recycling. Many countries have been developing strategies to demilitarize these energetic materials, with respect to safety, security and environmental consideration. Most demilitarization technologies are still in the laboratory level at the development process [1, 2]. However, if not possible to recover the valuable ingredients of the waste explosive compositions, it is preferable to use them to provide some form of useful energy than to destroy them.

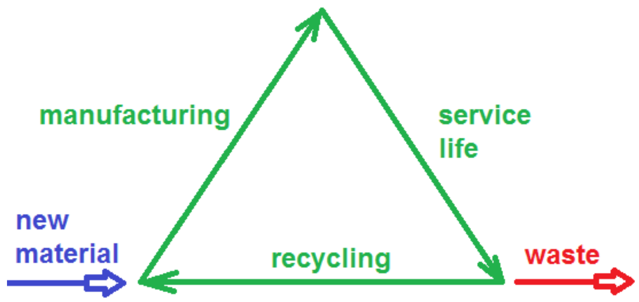

Figure 1: Scheme of the usual cycle of energetic compositions production

Cast-cured PBX explosives are composites with an explosive ingredient, with or without other solid ingredients as a metal powder fuel or some oxidizer, suspended in a polymer matrix binder. At the end of technological process of their production the polymeric matrix is cured and chemically irreversibly cross-linked, so these compositions are insoluble and non-recyclable. Most often, the polymer is an elastomeric inert binder such as hydroxyl-terminated polybutadiene (HTPB) cross-linked with an isocyanate, with addition of ingredients and additives for better processing characteristics or for longer shelf life. Besides HTPB, there are also other polymers in use, like carboxy-terminated polybutadiene (CTPB) and hydro-terminated polyethers (HTPE) [1].

At the moment when the waste PBX should be treated or safely disposed, there are various possibilities. Some efforts have been made to partially recover some of the PBX ingredients, but to do this; the cured PBX must be cut into very small pieces. Other options include their destruction in controlled conditions.

Mechanical bandsaw, that is remotely operated and cooled by water or some other cooling liquid, can be used to cut PBX. Waterjet cutting can be also used, but these two approaches produce contaminated wastewater that must be further treated. There are also techniques which include cryofracturing, cutting with high-pressure ammonia jets or femtosecond laser, but these methods are very expensive and require highly trained personnel. In addition to the above-mentioned techniques, there are acid digestion/dissolution method, various incineration systems, closed detonation in detonation chambers that are indirectly heated from outside, and finally, open burning and open detonation, as the most inexpensive and most technologically simple disposal methods. However, open detonation should be avoided since it releases a large amount of NOx gases, which are among major air pollutants. There are mobile incineration plants where energy from the energetic materials can be recovered for heating or electricity generation [1-3, 8-10].

Energetic materials such as most known explosives, like TNT, RDX, HMX, CL-20, etc. have the maximum heat of combustion limited by the enthalpy of formation of their reaction products, CO_2 and H_2O upon complete oxidation, and it is also important to note that this exothermic reaction occurs rapidly, but the energy densities of such materials are relatively low [11]. Higher combustion energies and energy densities are provided by the metal fuels present in thermobaric compositions, such as Mg, Al, B, and others [12]. The maximum gravimetric and volumetric reaction enthalpies for some often used explosives and for some metal fuels are given in Figure 2. However, micron-sized metal particles ignite after a certain delay as compared to the initiation of the explosive compounds due to slower heterogeneous reactions followed by the self-sustaining combustion of the metal powder particles. The nano-sized metal powders in combinations of conventional, micron-sized metal powders were proven to provide much better results regarding the thermal output [11].

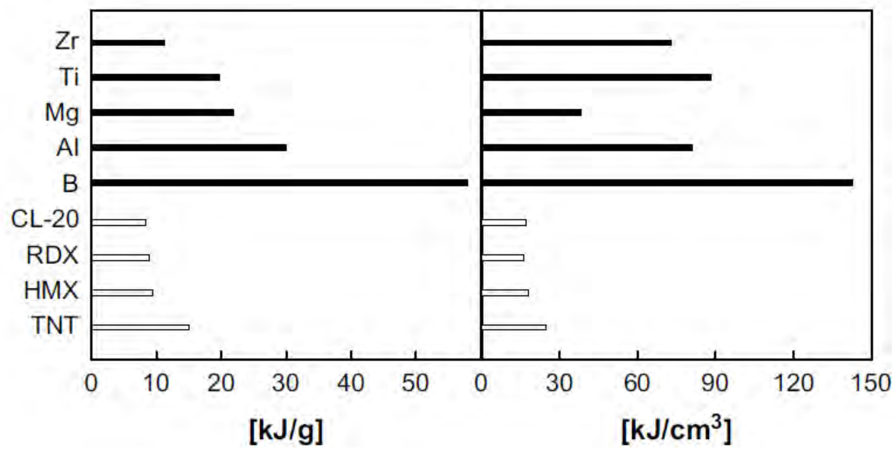

Figure 2: Combustion enthalpies for often used high explosives and metal fuels [11]

In this study, several compositions of cast-cured thermobaric PBX were analyzed in terms of their thermal output for potential use as a combustible material burned in controlled conditions. The observed compositions containing aluminium, magnesium and boron powder were prepared and their energetic potential was examined, but also numerical calculation of their thermal output was done using the EXPLO5 software, in isochoric and adiabatic conditions of combustion. Thermobaric explosives have a pronounced thermal output during the post-detonation combustion phase, due to the presence of metal powder fuel, which burns in contact with atmosphere oxygen or the oxidant component of the mixture after the detonation initiation. In this post-detonation process a high amount of heat energy is generated, which gave the idea that the waste of these PBX mixtures might serve as a potential source of heat energy that can be transferred to other forms of work energy or to electricity.

2 Materials and methods

Cast-cured PBX preparation was done according to internal technological procedure of Military Technical Institute [13], with the compositions given in Table 1. The following raw materials were used: HMX (Prva Iskra, Barič), AP (10 microns, Poliex), Al (5 microns, Alcan Toyo), Mg (10-20 microns, CATENA), B (1-5 microns, SpeedUp International), polymer binder based on HTPB (HB 70) cured with IPDI (Aldrich), with addition of DOA (Aldrich). The first two PBX compositions contained 15 wt.% of HTPB-based binder, but the composition containing boron was made with 20 wt.% of binder, since the boron powder causes significant increase in viscosity, thus affects the processability of the mixture [13, 14]. Although these three compositions did not have the same content of HMX or HTPB, they were chosen as real applicable compositions.

Table 1. Cast thermobaric PBX compositions

	HMX	*AP*	*Al*	*Mg*	*B*	*HTPB*
PBX -15/02	45	/	40	/	/	15
PBX -15/05	45	10	20	10	/	15
PBX -15/07	40	10	10	10	10	20

The selected compositions were experimentally examined by the calorimetric method, in order to determine their energetic potential during combustion in atmosphere of inert gas. The isoperibolic calorimeter *IKA-Kalorimeter C 2000* was used with calorimetric bomb *C 5010*. This test was carried out in an inert atmosphere of argon, under 30 bars of pressure in the calorimetric bomb.

Prediction of the thermal output of the thermobaric PBX compositions, under different combustion conditions, was carried out using thermodynamic code EXPLO5 V7.01.01 in isochoric and adiabatic combustion mode [15]. Virial equation of state of gas was applied. Calculations were done for loading density 1.6 g/cm^3.

3 Results and discussion

3.1 Calorimetry tests results

The results of the calorimetric examinations of the prepared PBX are given in Table 2.

Table 2. Energetic potential of the examined PBX in calorimetry test

	Heat of combustion, J/g			
Composition	test 1	test 2	test 3	Average value
PBX -15/02	3439.1	3304.4	3156.9	**3300.1**
PBX -15/05	5321.6	5100.4	5253.9	**5225.3**
PBX -15/07	4555.4	4502.2	4063.5	**4373.7**

Table 2 shows that the composition PBX -15/05, which contains a combination of Al and Mg had the highest heat potential, so it could provide the highest energy output in further use as a combustible material in controlled conditions. It is followed by the composition containing all three metal powders. This is consistent with the literature data where it was shown that aluminium powder is not easily ignitable, so it is helpful to combine it with some other metal fuel which is easier to ignite [12, 13, 16]. This is particularly evident in this test, which was carried out on very small samples, in argon, without any additional oxygen to support the combustion except the oxygen from the PBX itself. However, in open-air combustion, it was earlier shown by optical pyrometry and by infrared imaging technique that these thermobaric explosions provide very powerful detonation fireballs, but those conditions were different, when the violent reaction was expected [17]. In this inert atmosphere of argon in the present test, and limited quantity of the thermobaric compositions, the controlled combustion takes place and provides significant amounts of heat.

3.2 Thermal output of PBX predicted using EXPLO5

The results obtained in thermodynamic code EXPLO5 are given in Table 3. Before the thermal performance parameters, the oxygen balance of the chosen compositions is given, in order to better understand the results of the calculated thermodynamic parameters of the combustion products. As seen, the composition with all three metal powders and with the highest content of HTPB-binder has the lowest oxygen balance, even though the first PBX did not contain AP.

Table 3. Adiabatic and isochoric combustion simulation results

Combustion parameters	*PBX -15/02*	*PBX -15/05*	*PBX -15/07*
Oxygen balance	-93.522	-78.906	-107.204
Adiabatic combustion temperature (T_c), K	4363.60	4171.14	4014.15
Heat of isochoric combustion, kJ/kg	-7708.98	-7617.74	-7900.19
Heat of isochoric combustion [H_2O(l)], kJ/kg	-7713.1	-7625.90	-7926.87
Enthalpy of products (ballistic energy), kJ/kg	8065.25	7988.78	8203.40
Maximum pressure in closed vessel, MPa	4052.848	5844.212	5990.853
Force or 'specific energy' (F = nRT), MJ/kg	0.54592	0.66961	0.56972
Covolume of gaseous products, cm^3/g	0.240	0.290	0.254
Specific heat capacity at p=const. (C_p), J/kg K	2239.37	2417.13	2581.04
Specific heat capacity at V=const. (C_v), J/kg K	2139.39	2242.05	2453.08
Isochoric cooling of combustion products (from combustion temperature to room temperature)			
Combustion temperature, K	4363.60	4171.14	4014.15
Heat of combustion at T_c, kJ/kg	-7708.98	-7617.74	-7900.19
Heat of combustion at 298.15 K [H_2O(l)]*, kJ/kg	-9356.62	-9019.49	-9377.67
* corresponds to calorimetrically measured heat			

Despite its low oxygen balance, the first composition containing only Al, gives the highest adiabatic combustion temperature. The highest amount of released heat of combustion was observed for boron-containing PBX, as well as the highest specific heat capacities at both chosen conditions, constant pressure and constant volume. This means that such compositions, with a combination of metal fuels, would provide the highest energy during a controlled combustion process. The differences between the experimental and numerical results are a consequence of the applied test conditions: in the calorimetric bomb the samples burnt in argon. The only amount of oxygen present in this case was from chemical constituents (oxidiyer component – ammonium perchlorate and the nitramine explosive), so with the negative values of oxygen balance probably there was no complete combuston. In further work some other atmospheres should be examined as potential environments for this controled combustion in order to optimize the outcome (amount of heat energy released). In the same time, it is essential to remain in the "safe zone", regarding the potential danger of unwanted detonation, to avoid accidents like those that took place in explosive waste incinerators [10, 18, 19]. Probably mixtures of inert gas with small percentage of oxygen might provide more complete combustion, thus higher heat energy which could be further transformed to electrical energy.

4 Conclusions

Selected thermobaric PBX explosive compositions containing different metal fuel components were prepared and examined regarding the thermal output through calorimetric test and numerical approach using EXPLO5 to simulate isochoric and adiabatic combustion.

The calorimetry test in inert atmosphere of argon has revealed that PBX with a combination of Al and Mg had the highest energetic potential. EXPLO5 simulation results have indicated that the highest amount of released heat of combustion would be obtained for boron-containing PBX, as well as the highest specific heat capacities at constant pressure and constant volume. Experimental results differ from the numerical due to different test conditions. These results indicate that these or similar PBX compositions, with a combination of metal fuels, would provide the highest energy during a controlled combustion process.

The obtained results encourage further research into possible applications of this thermal energy which can be released not only in a destructive explosion reaction, but maybe also in controlled conditions for some industrial purposes – incineration of waste PBX to obtain some applicable form of energy, like heat which can be transformed to electric energy.

Acknowledgement: This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract No. 451-03-47/2023-01/200026, and University of Defense, Military Academy, Proj. No. VA-TT/1/22-24.

5 References

[1] **Poulin, I.**, *Literature review on demilitarization of munitions - Document prepared for the RIGHTTRAC Technology Demonstration Project,* Defence R&D Canada – Valcartier Technical Memorandum TM 2010-213, DRDC Valcartier 2010.

[2] **Explosives Industry Group Guidance for the Safe Management of the Disposal of Explosives,** *A guide to the safe disposal of explosives, the relevant legislation, the techniques used for disposal and associated risk control systems*, Confederation of British Industry , London 2007.

[3] *Alternative Treatment Technologies to Open Burning and Open Detonation of Energetic Hazardous Wastes*, Office of Resource Conservation and Recovery (5303P) | EPA 530-R-19-007 | 2019.

[4] **Anand S., Celin S.M.** Green Technologies for the Safe Disposal of Energetic Materials in the Environment. In: De Luca L.T., Shimada T., Sinditskii V.P., Calabro M., editors. *Chemical Rocket Propulsion: A Comprehensive Survey of Energetic Materials.* Springer International Publishing; Cham, Switzerland: 2017, 835–860.

[5] *Safe Disposal of Munitions, Design Principles and Requirements, and Safety Assessment.* NATO; Brussels, Belgium: 2001.

[6] **Sarah M., Stott, N.,** *Destroying Surplus Weapons.* United Nations Publication; New York, NY, USA: 2003.

[7] **Rotariu T, Moldovan AE, Toader G, Diacon A, Rusen E, Ginghina RE, Iorga O, Botiș HR, Klapötke T.** *"Green" PBX Formulations Based on High Explosives (RDX and HMX) and Water-Soluble pH-Sensitive Polymeric Binders,* Polymers (Basel). 2023 Apr 4;15(7):1790. doi: 10.3390/polym15071790.

[8] **Hashish, M. and Miller, P.L.,** *Cutting with high-pressure ammonia jets for demilitarization of chemical weapons,* Journal of Pressure Vessel Technology, 124(4), 2002, p. 487-492.

[9] **Roeske, F., Benterou, J., Lee, R. and Roos, E.**, *Cutting and machining energetic materials with a femtosecond laser*, Propellants, explosives and pyrotechnics, 28(2), 2003, p. 53-57.

[10] Federal Remediation Technologies Roundtable, *Remediation technologies screening matrix and reference guide*, *version 4.0: Thermal treatment technologies for explosives,* 2009.

[11] **Dreizin, E. L.** Metal-based reactive nanomaterials, Progress in Energy and Combustion Science, 35 (2009) 141–167, doi:10.1016/j.pecs.2008.09.001

[12] **Yen, N. H., Wang L. Y.,** *Reactive Metals in Explosives*, 37, 2012. Propellants Explos.Pyrotech., 143–155.

[13] **Simić, D.** *Cast thermobaric PBX explosives*- in Serbian (Liveni termobarični PBX eksplozivi), Scientific technical information - monography series, vol. 53(2), 2016. Military Technical Institute, Belgrade, ISSN 1820-3418.

[14]**Simić, D., Sirovatka, R., Andjelić, U., Bogdanov, J., Terzić S.,** *Thermobaric effect comparison of cast PBX and TNT in enclosure test*, 19th Seminar on New Trends in Research of Energetic Materials NTREM 2016, Pardubice, Czech Republic, 20-22th April 2016, Proceedings 947-953.
[15] **Sućeska, M.** EXPLO5 User's Guide, OZM Research, 2019.
[16] **Krstović, M., Bajić, D., Fidanovski, B., Timotijević, M., Terzić, S., Knežević, D.** *Application of calorimetry to estimate the thermal performance of thermobaric explosives*, 25th Seminar on New Trends in Research of Energetic Materials NTREM 2023, Pardubice, Czech Republic, 19-21th April 2023, Proceedings.
[17] **Simić, D.** Optimization of composition of cast PBX and examination of boron presence on thermobaric effect – technical report, in Serbian (Optimizacija sastava livenih TBE i ispitivanje uticaja prisustva bora na termobarični efekat, Tehnički izveštaj) Military technical institute, Belgrade, 2015.
[18] Review of Incidents at Hazardous Waste Management Facilities, Version 2.7. Environment Agency, 2013.
[19] Wolf, F. Contaminated waste incinerator modification study, Olin Corporation Badger, Army Ammunition Plant Baraboo, 1995.