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Investigation of Pyrotechnic Charges for Base Bleed Projectiles

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This paper shows the examination results of pyrotechnic compositions for the production of gas generator pyrotechnic charges based on an organic fuel-lactose and a metal powder-magnesium. The mixture ingredients were optimized to emphasize the influence of the composition on its functional characteristics and its ability to obtain desired effects of pyrotechnic charge properties (linear velocity, energetic potential, induction time and combustion product pressure). The examination results were compared, thus giving the information crucial for the determination of benefits/disadvantages of different fuel types.

Key words: **pyrotechnical mixture, gas generator, artillery projectile, magnesium, lactose, ascorbic acid, sorbitol, drag coefficient, test results.**

Nomenclature

C_D – Base drag coefficient,
p_B – Sub pressure behind the projectile base,
p_{max} – Maximum combustion products pressure value,
p_∞ – Air pressure,
M_∞ – Mach number,
k – Proportionality constant,
I – Impulse of combustion products into the surrounding air,
Tg – Combustion product temperature,
T_{ign} – Ignition temperature,
β – Projectile base drop angle,
$\dot{M}$ – Molar mass of pyrotechnic mixture,
dj/d_B – Combustion products exit hole radius to projectile base radius ratio,
t_d – Ignition delay time,
t_{max} – Time period for achieving the combustion product maximum pressure value.

Introduction

ENHANCING the range of classic projectiles is an ongoing activity of military industries all over the world. If we consider only a projectile as a whole and if we set its mass and muzzle velocity to have constant values, the parameter that could have a huge impact on its range is resistance that appears as a result of the projectile flight through the air. This resistance occurs due to its several components: wave, friction and base resistance [1].

The first two resistance components have been a subject of research from the early beginnings of ammunition development and nowadays they are set to their lowest values. As an impact of the first two components of resistance is almost marginalized due to technology improvements implemented in the production technology in past few decades, base drag resistance and its influence on the overall resistance has gained in significance.

Theoretical considerations

Base drag resistance appears as a consequence of the air flow around the projectile's base as it flies through the air from the gun muzzle to its target; consequently, a small sub pressure zone is formed behind the projectile's base. This specific zone is responsible for the "base drag" phenomenon and a decrease in the projectile's range. From the base drag coefficient equation (1) comes an obvious conclusion that the decrease of the sub pressure value results in the decrease of the base drag coefficient.

$$C_D = \frac{2\left[1-\left(p_B / p_\infty\right)\right]}{kM_\infty^2} \tag{1}$$

A solution to this problem, widely used in all military industries, is charging a gas generator unit (GGU) into the projectile's base. The increase of the projectile's range, in this case, goes hand in hand with the reduction of the base drag coefficient. The reduction of the base drag coefficient is obtained with a continuous flow of low-mass gaseous combustion products (which are generated in the combustion process of pyrotechnic charges in the combustion chamber of a GGU) into the near-wake zone behind the projectile's base. The purpose of these low mass products is to raise pressure in the sub pressure zone thus annulling its negative influence on the projectile's range. The efficiency of the GGU primarily depends on the projectile's aerodynamics and flight regime. The more the projectile is aerodynamically shaped, the greater is the effect of the GGU on the projectile's range. The participation of the base resistance in the overall projectile's resistance, the aerodynamic characteristics of which are set to their highest, can be up to 50 %. The research results [2] have shown that the base resistance coefficient is very complex and depends on a large scale of parameters. The most significant parameters are show in

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equation (2).

$$C_D=f\left(M_\infty,I,T_g,\beta,\dot{M},d_j/d_B,p_B/p_\infty\right) \tag{2}$$

If we remove the parameters that are closely connected to the projectile base structure (*dj*/*dB* and *β*) and the flight regime (*M*) from the equation above, it is obvious that the pyrotechnic mixture influence on the base resistance coefficient is closely connected with the GGU pyrotechnic parameters ($\dot{M}$, T_g and *I*).

Potential GGU charges of Base Bleed projectiles have to meet the following requirements:

- Physical and chemical stability within a storage period of ammunition they are charged into;
- Desired ignitibility with propellant combustion products while the projectile is still in the gun barrel;
- Stability of the combustion process through all phases of the projectile flight;
- Higher low-molecular gaseous to solid and liquid combustion products ratio;

In the beginning, gas generators were used only in large caliber artillery projectiles, and their charges were exclusively made of composite or double-based rocket fuels. Outstanding results in range enhancement pointed out to a possibility of achieving similar results with AA projectiles.

The first research in which pyrotechnic charges for GGUs were used instead of rocket fuel was based on a mixture with magnesium, strontium-nitrate, teflon and fluorel (MTV-mixture) as main components and in the ongoing text this composition will be referred to as a referent composition.

Looking at the main ingredients of the referent composition, we can see that it is very similar to MTV ignition mixtures [3, 4], known for their high burning temperatures, large quantities of both liquid and solid combustion products, high burning velocities and intensive flair. These characteristics, desirable when ignition mixtures are in question, in many ways could diminish desirable effects distinctive for GG mixtures. In that sense, some potential organic fuels like sorbitol ($C_6N_{14}O_6$), ascorbic acid ($C_6N_8O_6$), adipic acid ($C_6N_{10}O_4$), lactose ($C_{12}N_{22}O_{11}*H_2O$) and glucose ($C_6N_{12}O_6$) were taken into consideration [5]. The combustion of these organic fuels, besides significant heat output, and supposedly a generation of large quantities of gaseous products, mostly CO_2 and N_2O, provides extra oxygen atoms, stored in their molecular structure and available for a combustion process.

Experimental part

Pyrotechnic mixtures production technology

Production technology of pyrotechnic compositions consists of the several operations [6]:

- Preparation of mixture components,
- Measuring and dry homogenization of components,
- Preparation and dissolution of binder,
- Wet homogenization,
- Drying mixture to a state adequate for mashing,
- Mashing, and
- Evaporating all excessive solvent.

The component preparation is done strictly in accordance with adequate standards, especially focusing attention on the particle size and chemical purity of the components in question.

Dry homogenization represents the mechanical mixing of all mixture components. Dry homogenization is usually done manually, until all components are evenly dispersed. If a mixture consists of more than three components, dry homogenization is done in several phases.

A binder is resolved in a solvent and then added to the previously homogenized components in a so-called wet homogenization phase.

After the wet homogenization phase, excessive solvent is removed by drying to a state suitable for mashing. The mixture undergoing the mashing phase has to have some amount of solvent left for safety reasons.

The pyrotechnic mixture grains defined during the mashing phase are dried at 65°C out of all remaining solvent and then packed into hermetic containers or charged into pyrotechnic elements.

Defining a mixture composition for investigation

In order to focus on the impact of different fuel types on pyrotechnic mixture characteristics for the investigation presented in this paper, representatives of each fuel type were chosen - lactose for organic fuels and magnesium for high-energy metallic fuels. The compositions were made in accordance with adequate quality standards. The technology procedure was explained earlier. All components used for composition preparations had a middle particle size smaller than 100 μm. The mixture ingredients, with their mass portions that were the subjects of investigation in this paper, are presented in Table 1.

Table 1. Pyrotechnic mixtures investigated in the earlier phases of research

Composition label	Ingredient/mass portion [%]			
	Fuel	Oxidizer	Additive	Binder
Comp1/09	Lactose/25	$KClO_4$ [7]/70	–	Viton A/5
Comp.2/09	Lactose /20 Mg[8]/10	$KClO_4$/65	–	Viton A/5
Comp3/09	Lactose /17	KNO_3 [9]/63 $KClO_4$/15	–	Viton A/5
Comp4/09	Lactose /23	Fe_2O_3 [10]/9 $KClO_4$/63	–	Viton A/5
Comp5/09	Lactose /15	$KClO_4$/75	–	PF [11] /10
Comp6/09	Lactose /15	$KClO_4$/70	–	PF /15
Comp7/09	Lactose /15	$KClO_4$/70	Fe	PF /15
Comp8/09	Lactose /15	$KClO_4$/72.5	carbon/2,5	PF /10
Referent composition	Mg /40	$Sr(NO_3)_2$ [12]/40 PTFE/15	–	Viton A/5
Comp9/09	Lactose /10 Mg /15	KNO_3/60 $KClO_4$/10	–	PF /5
Comp10/09	Lactose /21	$KClO_4$/74	Fe(0.06g)	PF /5
Comp11/09	Lactose /21	$KClO_4$/74	–	PF /5

The components in Table 1 for which suitable quality standards were not mentioned were of commercial quality. The optimization process of mixture components was done so that the crucial information related to some critical characteristics of the combustion process such as ignitibility, combustion process stability, burning velocity, energy potential, etc. could be obtained.

Combustion process characteristics

Linear burning velocity

Linear burning velocity is a very important characteristic for all pyrotechnic mixtures. Since gas generator mixtures have to generate specific amount of gaseous combustion products in time in order to annul sub pressure formed behind the projectile's base, linear burning velocity defines the projectile range improvement by defining the flux of gaseous products. The investigation of linear burning velocity was conducted by pressing specific amounts of pyrotechnic mixtures into aluminum alloy tubes (height-15 mm, radius-8 mm and thickness of tube walls-2 mm) with 200 bar of pressure on the "DUNKES" hydraulic press, Fig.1 [13]. The mass of compositions to be pressed into aluminum tubes was measured on a digital scale with a third decimal precision. The height of the aluminum tube represented the linear burning velocity measuring range. Time measurements were done using an "Olympus" digital camera with a recording speed of 30 fps, which provides required precision for the expected range of linear burning velocities.

Figure 1. "DUNKES" vertical press

Energy potential

Energy potential is another important characteristic of all pyrotechnic compositions since it defines their range of use, stability and sustainability of the combustion process under specific application conditions. It is defined as amount of heat released through the combustion process of 1 g of pyrotechnic mixture in the vacuum or in neon or argon atmosphere.

Data obtained by calculations of mixture energy potential is based on anticipated chemical reactions since the whole range of possible parallel reactions is almost impossible to define. Therefore, it is used only for orientation purposes. Precise energy potential data for a specific mixture is gained through investigations in specialized appliances in accordance with the methodology defined in [14].

Figure 2. IKA C-2000 Isoperibolic calorimeter

The IKA C-2000 Isoperibolic calorimeter (Fig.2), fitted with the C5010 decomposition vessel was used for the measurements of energy potential in this investigation. The samples of mixtures for energy potential determination were given in the loose state (pyrotechnic mixture granules).

Combustion products pressure

While linear burning velocity determines the flux of gaseous combustion products, combustion products pressure gives us the first information on the composition gas generating possibilities and the participation of low-molecule gaseous combustion products in the overall amount of combustion products. The pressure of combustion products is a very distinctive characteristic, as a fingerprint, of every pyrotechnic mixture and is strongly influenced by the pyrotechnic mixture composition.

The pressure of combustion products is measured in a device similar to decomposition vessels used in energy potential measurements called manometric bomb (the volume of the bomb used in investigations is 300 cm^3). Every sample prepared for investigation consisted of 3 g of pyrotechnic mixture fitted with an electric igniter and packed into polyethylene containers. The containers were put into the bomb while the conducting cords of electric igniters were fitted onto the connectors on the bomb cover.

During examinations, the pressure probe (Teledyne Taber, Type 2210-measurement range is from 0 to 200 bar), fitted on the bomb cover was connected to a station computer which collected pressure value/time data with a sample period of $9.999997 x 10^{-5}$s.

Ignition temperature

Ignition temperature represents a temperature value at which a specific composition instantly ignites. The investigation method is very simple and it consists of a thermal block preheated to a specific temperature, with a hole in it for placing the composition to be investigated and a control unit used to preset the investigation temperature and the heating method. The induction time represents the time period from the moment a mixture is placed into the thermal block to the moment it ignites [15]. The mixture that is to be tested is in a loose form. The appliance used for the induction time measurements is shown in Fig.3.

Figure 3. Thermal block with its control unit

To obtain data that is more precise for the calculation of ignition temperature, five measurements for each of the minimum three investigating temperatures are required. The induction time of all measurements has to be between 3 and 10 s. The composition to be measured is placed into the heating block manually with a measurement cup with a capacity of approximately 0.05 g of mixture depending of its granulation.

Investigation results and disccusion

Linear burning velocity

In the initial phase of linear burning velocity all compositions presented in Table 1 were investigated and a wide spectrum of velocity values was obtained, going from 0.65 mm/s to 3.22 mm/s [16]. The linear burning velocity investigation results are shown in Table 2.

Table 2. Linear burning velocity investigation results

Composi-tion label	Combus-tion time, (s)	Linear burning velocity, (mm/s)	Combustion process remarks
comp.1/09	22.54	0.66	Stabile combustion without solid or liquid combustion products
comp.2/09	22.9	0.65	Similar burning velocity values as with comp. 1/09, solid and liquid combustion products were de-tected.
comp.3/09	–	–	Endothermic decomposition of KNO3 is too high to be reached with only organic fuel in composi-tion.
comp.5/09	13.6	1.1	Higher burning velocities as well as greater amount of solid and liq-uid combustion products were ob-tained.
comp.6/09	8.45	1.77	Higher burning velocity than with Viton A compositions.
comp.7/09	8.25	1.82	Substituting some portion of $KClO_4$ with PF in comp. 5/09 raised burning velocity.
comp.8/09	7.03	2.13	Adding just 0.02g of elemental iron to comp. 5/09 resulted in burning velocity increase for 5%.
comp.9/09	7.54	1.99	Substituting 2.5% of $KClO_4$ in comp.6/09 with carbon resulted in burning velocity increase for 12.5%.
Referent composition	10.03	1.5	Combustion process is followed by bright flair and the generation of large amount of solid and liquid combustion products.
comp.10/09	4.65	3.22	Combustion process is stabile with high burning velocity and small amount of solid and liquid com-bustion products.
comp.11/09	13.52	1.11	Compositions made to confirm a positive influence of elemental iron on burning velocity. The burning velocity of composition comp. 10/09 is 18% higher.
comp.12/09	15.89	0.94	

The linear burning velocity investigation results show that compositions with Viton A are slower than a composition based on PF (phenol formaldehyde resin) as a binder; consequently, compositions that were a subject of further and more detailed investigations were PF based. Compositions with Fe_2O_3 had higher burning velocities due to the increased thermal conductivity than those without Fe_2O_3. Small amounts of elemental iron have shown a significant impact on burning velocities, even in the smallest amounts, without negative effects such as increased mass of solid and liquid combustion products. Another possibility for increasing burning velocity is substituting a portion of the oxidizer with PF; however, the mashing phase was much harder due to the increased amount of the binder in the mixture.

Due to the request for a minimum value of linear burning velocity, which was set to 2 mm/s, compositions 9 and 10 with lactose and a referent composition with magnesium were chosen for further investigations.

Energy potential

The energy potential investigation was done only with the compositions chosen after the linear burning velocity testing and as it can be seen from the investigation results shown in Table 3, the energy potentials of compositions 9 and 10 are significantly lower, 43.3 and 33.9% respectively, than the energy potential of the referent composition [17].

Table 3. Energy potential results

Composition label	Energetic potential, J/g
comp. 9	4363.00
Referent composition	7698.95
comp. 10	5089.89

As it was mentioned in theoretical considerations, the similarity of the referent composition to MTV compositions pointed out that high energy values were to be expected. Over 40% higher energy potential of the referent composition in this matter is unnecessary, and consequently, because of higher heat strains, a thicker combustion chamber wall is needed. Therefore, the projectile mass accumulates, thus shortening the projectile range. Moreover, it is well known that MTV mixtures combusts at temperatures well over 2000°C [3], so if we assume that the gas generator should be working during the whole projectile flight to increase the range as much as possible, then the assumption that the projectile explosive charge is thermally jeopardized is reasonable. The observed increase in the energy potential between two lactose-based compositions is related with the presence of a high-energy fuel, magnesium, in comp 10.

Ignition temperature

The ignition temperature investigation results for the compositions chosen for a more detailed analysis are shown in Tables 4, 5 and 6 and graphically presented in Fig.4.

Table 4. Induction time investigation results for comp 9

Temperature, [°C]	Induction time, [s]					Middle value	$y = -5,7796x + 560,66$ $T_{IgnT}(X=0)=560,66^{o}C$
500	10.8	10.1	11.1	10.3	10.6	10.6	
510	8.4	8.6	8.6	8.7	8.7	8.6	
530	5.3	5.3	5.5	5.6	5.1	5.4	

Table 5. Induction time investigation results for comp 10

Temperature, [°C]	Induction time, [s]					Middle value	$y = -9.4021x + 544.95$ $T_{IgnT}(X=0)=544.95^{o}C$
470	7.2	8.0	7.8	7.9	8.6	7.9	
500	4.8	4.5	5.3	4.8	4.9	4.9	
510	3.6	3.9	3.3	3.7	3.5	3.6	

Table 6. Induction time investigation results for the referent composition

Temperature, [°C]	Induction time, [s]					Middle value	$y = -17.385x + 800.52$ $T_{IgnT}(X=0)=800.52^{o}C$
650	8.4	8.6	8.6	8.4	9.0	8.6	
660	8.1	8.1	8.3	8.0	8.5	8.2	
680	8.8	7.0	6.8	6.0	5.9	6.9	

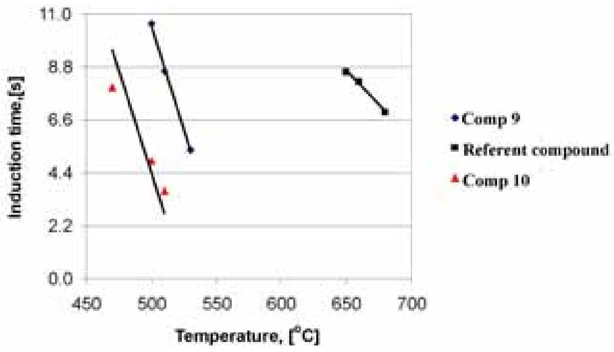

Figure 4. Induction time vs temperature diagram

From the induction time values presented in tables above, the ignition temperatures for each pyrotechnic composition with the induction time set to zero were calculated.

The highest ignition temperature was found in the referent composition, over 800°C, and the lowest one in comp 10, about 545°C. The lowest ignition temperature of comp 10 is obtained through better conductivity achieved by adding magnesium into the lactose-based mixture and in combustion process of $KClO_4$ in liquefied lactose the decomposition temperature of which is about 230°C. The heat output of the combustion process of $KClO_4$ in liquid lactose is not as substantial as that at higher temperatures, but it contributes to the temperature rise of the whole system and consequently lowers the temperature needed for instantaneous ignition.

Combustion product pressure

The combustion products pressure investigation results are graphically presented in Fig.5, 6 and 7, while the middle values of all measured parameters are given in Table 7.

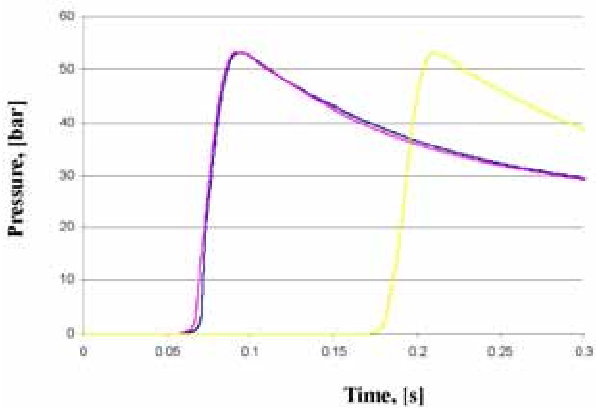

Figure 5. Combustion products pressure vs time diagram – comp 9

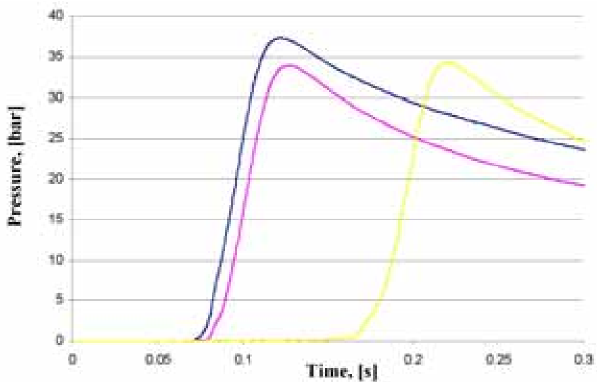

Figure 6. Combustion products pressure vs time diagram – referent composition

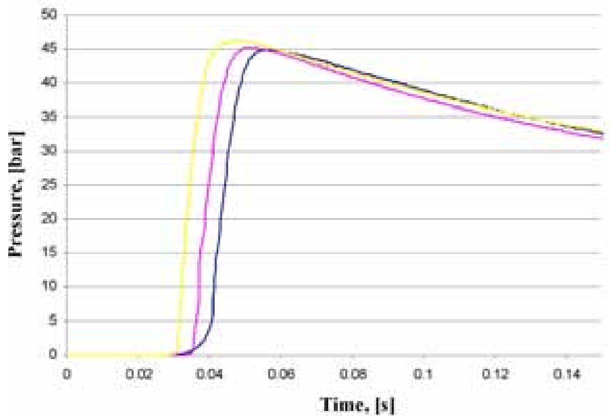

Figure 7. Combustion products pressure vs time diagram – comp 10

Table 7. Combustion products parameters investigation results

Composition label	Comp 9			Referent			Comp 10		
Measured parameters	t_d [ms]	t_{max} [ms]	p_{max} [bar]	t_d [ms]	t_{max} [ms]	p_{max} [bar]	t_d [ms]	t_{max} [ms]	p_{max} [bar]
1	0.065	0.094	53.3	0.073	0.122	37.4	0.033	0.057	44.9
2	0.062	0.093	53.4	0.080	0.129	33.9	0.035	0.053	45.2
3	0.176	0.213	53.2	0.160	0.221	34.3	0.030	0.048	46.2
Parameter middle value	0.101	0.133	53.3	0.104	0.157	35.2	0.033	0.053	45.4

From the data given in table above, it is obvious that the lactose-based compositions generate greater amounts of gaseous products for the same mass of mixture, hence the difference in the pressure values obtained through the investigation in the manometric bomb. The highest pressure value was found in comp 9, 53.3 bar, and the lowest one in the referent composition, 34% less - 35.2 bar, while the middle pressure value of 45.4 bar was found in comp 10. The difference in the maximum pressure values, between lactose- and magnesium-based compositions, was expected since the initial linear burning velocity tests have stressed the predisposition of the referent composition to produce huge amounts of solid and liquid combustion products. Neither solid nor liquid combustion products participate in raising pressure in the manometric bomb.

Conclusion

The comparison of the investigation results of both organic and metallic fuel-based pyrotechnic mixtures has shown significant differences in all observed combustion process characteristics. During the investigation, in the case of lactose-based compositions, a wide spectrum of linear burning velocities was obtained throughout improvements in their conductivity and energy potential. Even the smallest percentages of iron and Fe_2O_3 added to lactose-based compositions had a significant impact on their linear burning velocities. Greater portions of these additives were avoided due to their preference to generate larger amounts of unwanted solid and liquid combustion products. Lower energy potential values, over 40% less than for the referent composition, were a result of high-energy fuel deficiency in lactose-based compositions, unlike in the referent composition. Furthermore, degradation process of $KClO_4$ diluted in liquefied lactose at lower temperatures, significantly contributed to its 32% lower ignition temperature than in referent composition. A 3% difference in the ignition temperature between two lactose-based mixtures was attributed to the increase in conductivity of comp 10 presented with magnesium as a second fuel component. The combustion products pressure investigation confirmed the assumptions present from the beginning, so comp 9 with the lowest energy potential had the highest combustion pressure values observed throughout this investigation (53.3 bar). A high-energy fuel used for the composition preparations, magnesium, besides its positive impact on linear burning velocity and higher energy potential values, produces mainly solid and liquid combustion products which do not participate in pressure build-up, hence lower pressure values for comp 10 and the referent composition.

The next phase of the investigation should focus on observing the differences between various organic fuels for the purpose of composition components optimization leading to obtaining as good GGU performances as possible and to polygon testing which will give us the first information regarding the combustion process stability of the investigated compositions in dynamic conditions that occur during the projectile flight. The worst-case scenario that could happen to lactose-based compositions is closely related to their low energy potential and thermal conductivity which could jeopardize their combustion process stability in the dynamic flight regime of AA projectiles, the same properties that gave them absolute advantage over the referent composition in this phase of research.

Nevertheless, having in mind that the components for lactose-based compositions are much cheaper and easier to obtain, and that they generate preferably low-molecule gaseous products like CO, CO_2, H_2O, etc., through their combustion process, aswell as that their low energy potential significantly reduces the thermal stress of all surrounding GGU components, it can be said that they posses a high potential as high–efficiency pyrotechnic charges for Base Bleed gas generators.

Literatura

[1] SUBOTIĆ,Z., JARAMAZ,S.: *Izveštaj sa konstrukcionih ispitivanja probnih komada gasogeneratora za TF projektil 152 mm M-84*, Vojnotehnički intitut, TI-02-01-0238, Beograd, Serbia, 1989.

[2] INJAC,M.: *Spoljnobalističke mogućnosti povećanja dometa artiljerijskih projektila 130mm i 152mm primenom gasogeneratora*, TI-02-27-116, Beograd, 1984.

[3] FARID,C.CHRISTO: *Thermochemistry and Kinetics Model from Magnesium/Teflon/Viton pyrotechnic components*, Aeronautical and Maritime Research Laboratory, DSTO-TR-0938, Melbourne, 1999.

[4] de YONG,L.V., SMIT,K.J.: *A theoretical study of the combustion of Magnesium/Teflon/Viton pyrotechnic compositions*, MRL-TR-91-25, 1991.

[5] GREENE,R.W.:*Solid pyrotechnic compositions for projectile base-bleed systems*, United States Patent 5056436, 1991.

[6] KAPOR,S.: *Opšti tehnološki postupak izrade pirotehničkih smeša*, TI, VTI-004-01-0428, 2006.

[7] SORS 1368 Kalijum-perhlorat.

[8] SORS 1404/01 Magnezijum u prahu.

[9] SORS 1403/02 Kalijum-nitrat

[10] SORS 2468/89 Gvožđe (III)-oksid. Zahtevi za kvalitet i metode ispitivanja.

[11] SORS 1400 Fenolformaldehidna smola.

[12] SORS 1397/05 Stroncijum-nitrat.

[13] BOŠNJAKOVIĆ,M.: *Osvajanje postupka merenja brzine gorenja pirotehničkih sastava*, TI-277, 1973.

[14] STANKOVIĆ,M.: IS-042104, *Interni standard za kalorimetrijsko ispitivanje eksplozivnih materija*, 1992.

[15] BOŠNJAKOVIĆ,M.: *Osvajanje postupka merenja temperature paljenja i vremena indukcije*, TI-320, VTI, Beograd1974.

[16] PAŠAGIĆ,S., PETKOVIĆ,J.: *Usage of organic substances as fuels in production of gas generator pyrotechnic charges for Base Bleed projectiles*, 4th International Scientific Conference OTEX 2011, Belgrade, Serbia, October 2011.

[17] PAŠAGIĆ,S. PETKOVIĆ,J.: *Organic substances in production of gas generator pyrotechnic charges*, Military technologies and systems conference, Bulgaria, December 2011.

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Istraživanje pirotehničkih smeša za izradu punjenja generatora gasa base bleed projektila

U ovom radu su prikazani rezultati ispitivanja pirotehničkih smeša za izradu punjenja generatora gasa na bazi organskog goriva – laktoze i metalnog praha – magnezijuma. Sastavi pirotehničkih smeša su optimisani u cilju naglašavanja uticaja sastava na funkcionalne karakteristike i mogućnosti postizanja željenih efekata pirotehničkih punjenja (linearna brzina sagorevanja, energetski potencijal, vreme indukcije i maksimalni pritisak produkata sagorevanja). Poređenje dobijenih rezultata ispitivanja obezbedilo je bitne informacije za definisanje prednosti i mana korišćenja različitih gorivih komponenti.

Ključne reči: **pirotehnička smeša, generator gasa, artiljerijski projektil, magnezijum, laktoza, askorbinska kiselina, sorbitol, koeficijent otpora, rezultati ispitivanja.**

Тестирование функциональных характеристик пиротехнических зарядов base bleed снарядов

В статье представлены результаты тестирования функциональных характеристик пиротехнических смесей для производства зарядки газогенераторов Base Bleed снарядов. Пиротехнические смеси различных органических видов топлива производятся ради наблюдения различий их функциональных характеристик (линейная скорость горения, влияние давления прессования на линейную скорость горения и на устойчивость процесса сгорания), а в том числе и сравнений с функциональными характеристиками ссылкой распределения (с магнием в качестве основного компонента топлива).

Ключевые слова: **пиротехническая смесь, газогенератор, артиллерийский снаряд, магний, лактоза, аскорбиновая кислота, сорбит, коэффициент лобового сопротивления, результаты тестов.**

Les recherches sur les caractéristiques fonctionnelles des charges pyrotechniques pour les projectiles Base Bleed

Dans ce papier on présentera les résultats des essais sur les caractéristiques fonctionnelles des mélanges pyrotechniques pour la production des charges pour le générateur de gaz des projectiles Base Bleed. Les mélanges pyrotechniques de différents carburants organiques sont faits pour montrer les différences de leurs caractéristiques fonctionnelles (vitesse linéaire de combustion, influence de la pression de pressage sur la vitesse linéaire de combustion et stabilité du processus de combustion) ainsi que la comparaison avec les caractéristiques fonctionnelles de la composition référentielle (avec le magnésium comme la principale composante combustible).

Mots clés: **mélange pyrotechnique, générateur de gaz, projectile d’artillerie, magnésium, lactose, acide ascorbique, sorbitol, coefficient de résistance, résultats des essais.**