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INFLUENCE OF DIFFERENT IGNITION SYSTEMS ON THE INTERIOR BALLISTICS OF AN EI-PROPELLANT

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The influence of eight different ignition systems on a high performance EI-Propellant in a 25 mm APFSDS-T / KBA-gun configuration was investigated. It could be shown that under identical firing conditions the ignition strongly influences important ballistic parameters like ignition delay time, temperature dependence of the gas production rate of the EI-Propellant and muzzle velocity. In a special closed bomb the pressure development as a function of time was investigated for all eight igniter systems. Igniters with a fast pressure rise and a relative high equilibrium pressure are essential for the applied EI-Propellant to get best ballistic performance with lowest temperature dependence. To develop highly performing ammunition systems it is therefore necessary first to find an efficient and system-compatible ignitor for a propellant type and then optimize this propellant type to the ammunition configuration.

INTRODUCTION

Extruded Impregnated Propellants (EI-Propellants) are highly performing propellants especially designed for sub-caliber ammunitions in the medium caliber range. Due to a slightly increased energy content, a highly progressive burning behavior, a reduced temperature dependence of the gas production rate and a increased bulk density compared to single base propellants, a significant ballistic performance gain under system-compatible conditions can be achieved with EI-Propellants [1].

Very often ammunition parameters like ignition system, projectile type and loading volume are already defined, when the propellant manufacturer has to develop the corresponding propellant to reach maximum muzzle velocity within the pressure limits of the weapon system.

Presumably the whole propellant system (ignitor and propellant) has to be tuned and optimized in order to get the highest possible performance of a weapon system in a given caliber.

OBJECT OF INVESTIGATION

The object of this investigation was to show the influence of different ignition systems on the performance of a defined 25 mm caliber KBA ammunition system loaded with a preselected high performance EI-Propellant. Especially the following points had to be carefully elucidated:

Pressure rise (performance) of the different igniters and the influence of this parameter on the ignition delay time (t_2), temperature dependence of the gas production rate of the EI-Propellant and muzzle velocity.

EXPERIMENTAL

Ammunition Compounds

Four commercially available cartridges with integrated ignitors and one cartridge with four different, exchangeable ignition screws were investigated. The five different cartridges used are made out of different steels or alloys. Due to the fact that the pull out resistance of the projectile is a very important parameter to be kept constant for all cartridges in order to correctly see the influence of the ignition system on the performance of the EI-Propellant, a special APFSDS-T with an ideally sized groove in the discarding sabot was selected as projectile. Together with a rubber ring crimp system it was possible to fix the projectile on all different cartridges with the same pull out resistance.

The used tungsten arrow and the discarding sabot had a constant weight of 132.76 $\pm$ 0.04 grams.

Despite of having the same caliber, the cartridges show different loading volumes due to slightly different geometries and igniter volumes.

In Table 1, all used cartridges, their loading volume, the corresponding igniter system and the applied crimp force to get the constant pull out resistance of the projectile of 11.0 ± 0.5 kN are indicated.

Table 1

Cartridge	**Volume (cm^3)**	**Igniter**	**Crimp Force (kN)**
EXP-NC	102.26	336 mg Nitrocellulose	153
EXP-TI	102.50	275 mg $Ti/KClO_4$	153
EXP-BP	102.41	1100 mg Black Powder	153
EXP-TIH	102.57	315 mg $TiH/KClO_4$	153
COM-CO	107.31	Sinoxid	210
COM-TA	103.42	Not available	155
COM-RP	103.85	Not available	150.5
COM-EM	105.08	Not available	180

Propellant Selection

The goal of this investigation was to test the influence of different igniters on the ballistic performance of an EI-Propellant under realistic conditions. Therefore a suitable EI-Propellant had to be selected which can be filled at the highest possible loading density into all eight cartridges without developing peak pressures above the limits of the weapon system over the whole firing temperature range. Consequently the EI-Propellant to be selected must not necessarily show highest performance in one or more of the eight ammunition systems but good performance in all cartridges. Therefore the selection was made between EI-Propellants which were optimized for other 25 mm caliber ammunition configurations than the ones chosen to be investigated.

The influence of different loading volumes in all eight cartridges (102.3 – 107.3 cm^3) was compensated by using always the same loading density of 0.95.

After a preliminary selection between several available EI-propellants, finally two different types of suitable EI-Propellant were tested in all cartridges with all eight igniters under varying loading densities at 21°C. The propellant with higher loading density at lower peak pressure level was selected. Further investigations with this EI-Propellant over the whole temperature range gave the highest possible loading density for all ammunition configurations and firing temperatures without crossing the pressure limit of the 25 mm KBA barrel.

Ignitor Characterization

The performance of all commercial and experimental ignitors were investigated at 21°C in a special closed bomb equipped with two pressure transducers. Each type of ignitor was fired 5 times under identical conditions and the resulting pressure-time curves were superimposed, leading to a average curve.

Firing Conditions

All firing parameters were kept constant and only the ignitor was varied. The 25 mm KBA barrel was almost new with a firing count of only 400 rounds. All important firing parameters are shown in Table 2.

Table 2

Parameter	Value
Barrel	25 mm KBA No. 86078 (Oerlikon Contraves Pyrotec, OCP)
Chamber	25 mm wedge type breech block No. 7505 (OCP)
Projectile	25 mm APFSDS-T, 132.76 ± 0.04 grams, Lot OE 007-97 (OCP)
Pull out resistance	11.0 ± 0.5 kN for all cartridges
Loading density	0.95 for all cartridges
Firing temperatures	–54°C, –30°C, +21°C, +52°C, +71°C for each ignition system
Shots	5 at each temperature

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RESULTS

Ignitor Performance

Figure 1 shows the pressure rise as a function of time for all commercial ignitors. Due to the very similar time dependence of the pressure curves and the same equilibrium pressure, it is very probable that the cartridges COM-CO and COM-EM are equipped with the same type of igniter. COM-TA has a short-time peak pressure clearly higher than all others (about 160 bar) and a similar equilibrium pressure like COM-RP.

Figure 1.

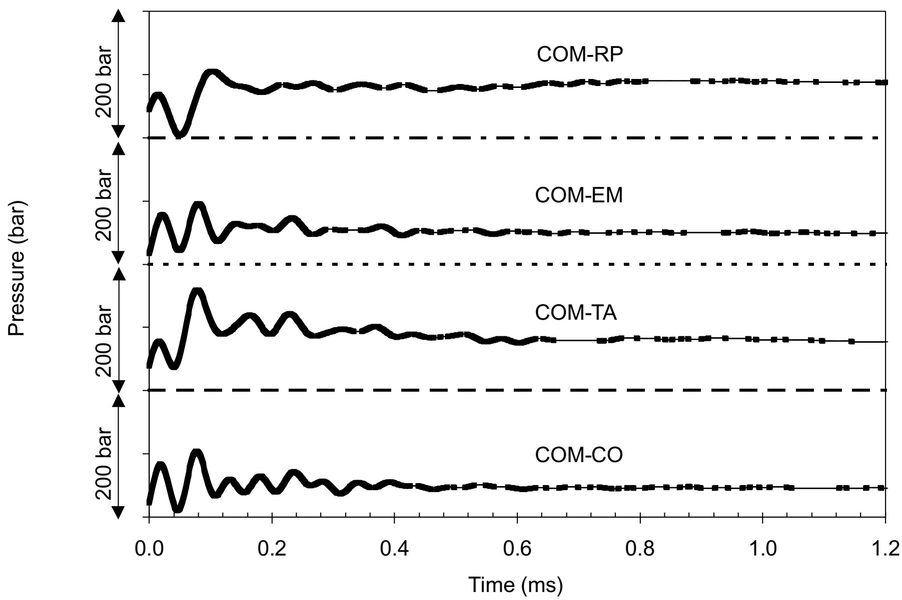

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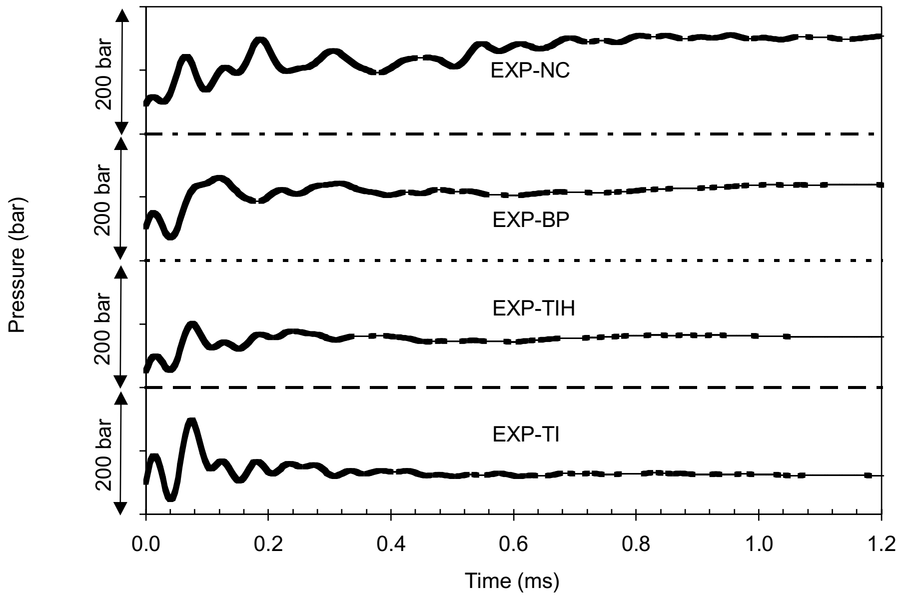
Figure 2 shows the pressure-time curves of all experimental igniters. EXP-NC, EXP-BP and EXP-TI have all short-time peak pressures well above 100 bar. The equilibrium pressure for EXP-NC is extremely high at 150 bar, whereas for EXP-BP it is at 120 bar and for EXP-TI it is only at 60 bar. EXP-TIH has a short-time peak pressure of 100 bar and an equilibrium pressure of 80 bar.

Figure 2.



Despite the fact that the quantity of igniters in all cartridges varies or even is unknown (see Table 1), these ignitors are especially made for 25 mm caliber ammunition systems. If only the gas production of the ignitors is considered, the performance is highest in EXP-NC and EXP-BP and lowest in COM-CO, COM-EM and EXP-TI. Porous nitrocellulose and black powder are known to produce hot gas whereas Ti-containing ignitors produce mainly hot particles.

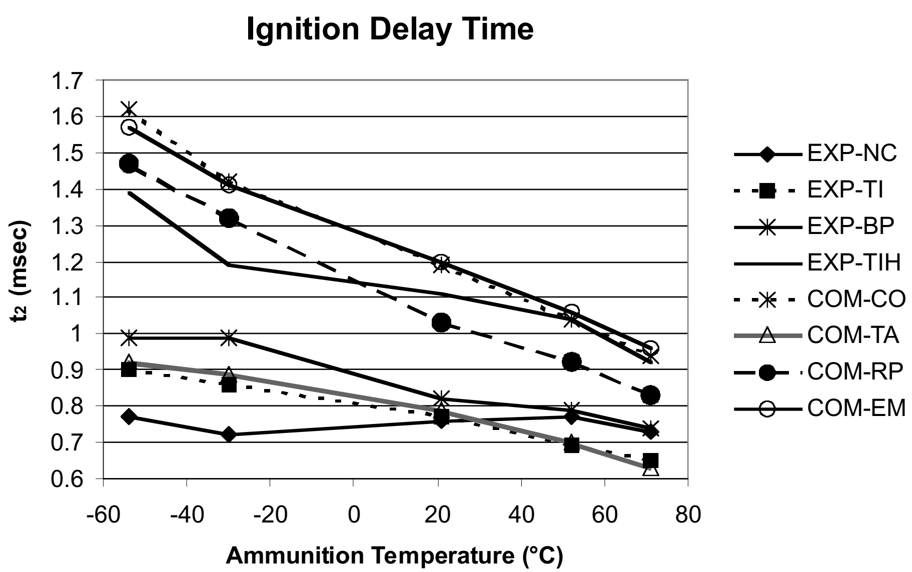
Ignition Delay Time

Figure 3 shows clearly that the ignition delay time (t_2) is heavily depending on the ignition. Moreover the igniters can be divided into two groups : one group showing a high temperature dependence and longer ignition delay times, the other group having only low temperature dependence and short ignition delay times.

Comparing the ignition delay time with the pressure-time curves in Figure 1 and 2 leads to the assumption that ignitors with a high short-time peak pressure (as measured in the closed bomb) give a faster and less temperature depending ignition with this particular

EI-Propellant, almost independent of the total quantity of hot gas or hot particles produced. All primers (COM-CO, COM-EM, COM-RP and EXP-TIH) leading to long ignition delay times show short-time peak pressures equal to or below 100 bar.

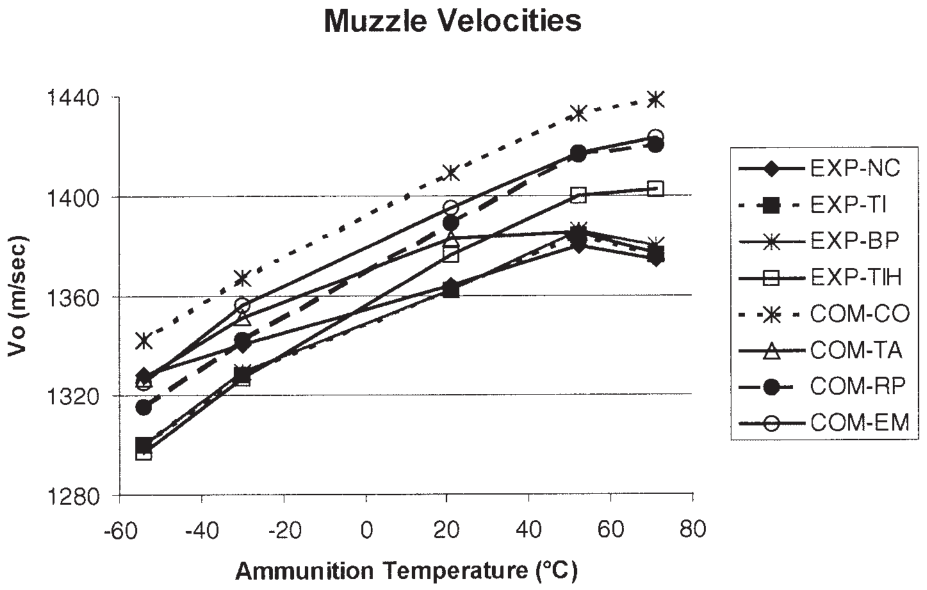
Figure 3.



Muzzle Velocity

A similar dependence exists between the ignition system and the temperature dependence of the muzzle velocity as can be seen in Figure 4. All ignitors with low short-time peak pressure curves lead to a high temperature dependence of the muzzle velocity. At high temperatures COM-CO for example is at the pressure limit of the weapon system with a corresponding high muzzle velocity. All initiators with a high short-time peak pressure yield a gas production rate which is less temperature depending. The pressure maximum is also clearly below the limits which means that the loading density of such an ammunition system can easily be enhanced to higher values resulting in higher mean velocities over the whole temperature range.

Figure 4.



CONCLUSION

This study demonstrates impressively the big influence of different ignition systems on the interior ballistic behavior of an EI-Propellant.

Despite the possibility to develop a suitable EI-Propellant for every ignition system, it will be necessary first to find an efficient ignitor for a suitable propellant type and then optimize this propellant to get an ammunition system with superior performance. Therefore it is indispensable that ammunition manufacturers and propellant producers work closely together in order to develop best performing weapon generations.

REFERENCES

1. B. Vogelsanger, K. Ryf, 29th International Annual Conference of ICT, 1998