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HIGH PERFORMANCE PROPULSION DESIGN FOR FUTURE KINETIC ENERGY AMMUNITION

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In the past an increase of performance of propulsion systems was reached by raising the energy content of the propellants.
So the explosion heat of propellant formulas for higher kinetic energy ammunition was increased from 4700 J/g (DM 23 / DM 33) to 5000 J/g (DM 53).
But a full utilization of the interior ballistic possibilities can only be performed, if it can be reached to exhaust the gas pressure limits of the gun tube by producing temperature independent burning propellants.
For this Nitrochemie pursues two directions:
1. Application of special burning regulators by surface coating of propellants with conventional in service compositions
2. Replacing of the blasting oils as NG or DEDGN by new energetic plasticizers in order to offer an increase of performance with low erosion and less sensitivity

On the basis of these technologies an improvement of propulsion energy from 5–10% can be expected. Besides Nitrochemie performs some development work for the optimization of the combustible cartridge cases. The web size of these materials, which are produced by the felted fibre technology, needs to be reduced in order to increase the inner volume and the charge weights. From this we expect another 5–10% of an improvement of performance. By combining an optimization of propellants and combustibles we hope to be able to offer attractive products for future high kinetic energy ammunition.

INTRODUCTION

One of the competences and strategic positions of Nitrochemie is the development and production of components for high performance gun ammunition for the whole caliber range.

In the international market this competence was proved successful by transforming into serial production for several applications.

In connection with future developments mainly for tank gun ammunition this competence shall be improved. Here the following parameters must be considered:

1. Application of a formula, which concerning thermodynamic and mechanical properties corresponds to the required performance
2. Achievement of a temperature insensitive burning characteristics
3. Optimization of the charge weight by reducing the volume of the cartridge case
4. Reaching this increase of performance with system compatible conditions which means with as little erosion and vulnerability as possible

PRODUCT CONCEPTION

To maximize the penetrating power of projectiles by utilizing the advantages of new technologies is a challenge we want to accept mainly in the field of tank gun ammunition.

Here the following modern basic technologies should be considered:

– Use of high robust materials for the gun tubes which could allow higher gas pressures
– Application of projectiles with higher robust heavy metals and concerning slenderness optimized geometry
– Application of lighter propellant retainers by use of the most modern material technology
and of course
– By the utilization of all interior ballistic posibilities for the ammunition

Considering the values of the performance of in service ammunitions the margin for further developments seems to be narrow.

Nevertheless the characteristics of conventional propellants show tbat there indeed exist some reserves which can be utilized.

Characteristically the burning velocity of conventional propulsion systems increases with higher temperatures (diagram 1).

DIAGRAM 1

Linear Burning Rate of a Propellant based on Nitrocellulose in Function of the Starting Temperature

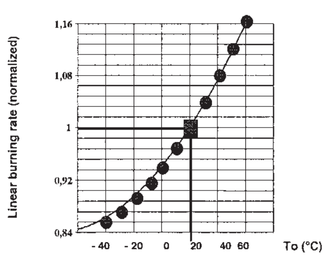
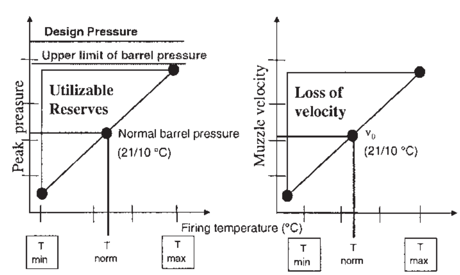


DIAGRAM 2

Characteristic of Common Propellants



Therefore the values of gas pressure and velocity show a more or less high temperature gradient.

This temperature dependent behaviour of the ammunition causes some serious disadvantages

- Lower probability of a hit with the first shot
- Considerably lower projecile energy especially at low temperatures

Typically the limiting factor is the maximum gas pressure at high temperatures. Also in the upper temperature range no single pressure value may exceed the maximum permissible pressure of the weapon tube.

As diagram 2 shows there would be an important potential for an increase of peformance if one could realize a temperature insensitive burning behaviour for the propellants.

Therefore one of our primary directions of impact is the development of temperature independent propellants.

Besides we also want to fulfil the following requirements for future propellant types:

- Chemical stability for the use of minimum 20 years
- High specific energy
- Reproducable temperature insensitive behaviour
- Good mechanical stability
- Low erosion
- Low sensitivity against special stress
- High loading densities for the full utilization of a maximally available potential of performance

In this narrow room a maximum increase of performance only can be obtained by the combination of several suitable steps.

Therefore the conception for the development of future high performance ammunition plans the following steps with propellants and combustible cartridge cases.

1. Optimization of combustible cartridge cases concerning the mechanical stability and reduction of the web size, in order to obtain an increase of charge weight by the *enlargement* of the *total volume* of the *cartridge case*
2. Application of propellant formulas with *high specific energies* which correspond to the required performance data
3. *Optimization* of the *densities* of those *propellants* to be able to reach maximum charge weights
4. Development of *propellants with progressive burning characteristics* by using a suitable geometry in combination with special burning regulators
5. Realization of an ammunition with an approximately *temperature insensitive burning behaviour*

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Optimization of Combustible Cartridge Cases

Combustible cartridge cases have been produced since more than twenty years and are successfully used in tank gun and artillery ammunition.

The maximum charge weight often is limited by the volume of the cartridge case. In order to be able to use the maximum loading densities for future propulsion systems, the optimization of this component of the ammunition also is necessary.

The main goal of our development work is an improvement of the mechanical stability of the combustible cartridge cases in order to be able to achieve a significant reduction of the web size and thereby to reach an extension of the inner volume of the cartridge.

Therefore the following parameters are studied:

– New resin mixtures
– Incorporation of additives which can improve the mechanical strength
– Optimization / modification of usual components of the combustible cartridges

Within the scope of this work at first the potential for an improvement of these parameters is studied basically in the laboratory scale. There values for the tensile strain are determined.

Afterwards these results have to be reproduced by means of samples of the pilot plant.

Diagram 3 shows results of the tensile strain of combustible cartridge cases with different resin variations.

For comparison the values of an in service cartridge for the 120 mm, DM 53 are also demonstrated. The results show a significant improvement concerning fracture strength of factor 2, concerning energy absorption of factor 4.

In diagram 4 these results are shown for combustible cartridges, where usual modified components were incorporated partly combined with strength improving additives. Here also a significant improvement of the values for the tensile strain could be detected.

After these encouraging results it must be shown in further investigations (per example in environmental test), if these conceptions indeed allow a reduction of the web size in order to improve the charge weights for new propulsion systems.

DIAGRAM 3

Optimisation of the Mechanical Stability of Combustible Cartridge Cases
Modifications of the Binder Systems

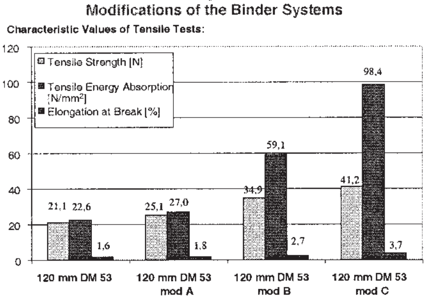
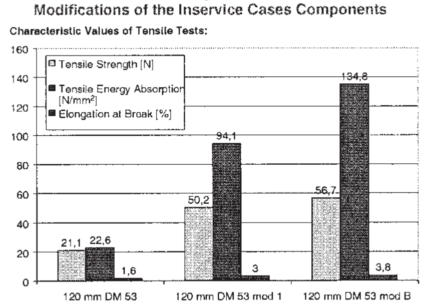


DIAGRAM 4

Optimisation of the Mechanical Stability of combustible Cartridge Cases
Modifications of the Inservice Cases Components



Optimization of Propellants

To be able to survive in competition for future development programs with an attractive conception, the investigations for the realization of propellants with temperature insensitive burning characteristic have already started in the 80s.

During the last years Nitrochemie basically has persued with the main emphasis on two different conceptions:

1. The application of special burning regulators on in service two or triple base formulas by surface coating
2. The development of new propellant compositions where the blasting oils as diethylenglycoldinitrate (DEGDN) or nitroglycerine (NG) are replaced by new energic plasticizers. So a temperature independent burning characteristics can be reached under especially agreeable conditions for the weapon systems.

Surface Coated Conventional Propellants

On principle surface coating agents have to fulfil the following requirements:

1. Chemical compatibility with the base materials
2. Sufficient penetration depth in the propellant matrix
3. Diffusion stability of the deterrent
4. Sufficient coating effect
5. Ignitability of the coated propellant surface

A lot of investigations were performed, where the above described criteria were checked. Within the scope of this work some suitable materials could be found. In order to avoid a loss of energy it is necessary only to use very small concentrations of the burning modifier. Therefore the process engineering had to be optimized too.

As mentioned before the conception for the surface coating was developed some years ago for improved 105 mm ammunitions.

When the limits for the 120 mm tank gun were newly defined, for an increase of combat efficiency the conception of the temperature independent surface coated propellants was adapted for 120 mm ammunitions also. This work was performed in cooperation with the Rheinmetall Company.

In diagram 5 gun firing test results at different temperatures in a 120 mm ammunition of a surface coated propellant are shown in comparison to the values of a conventional solventless high energetic propellant. For the test a L44 barrel was used.

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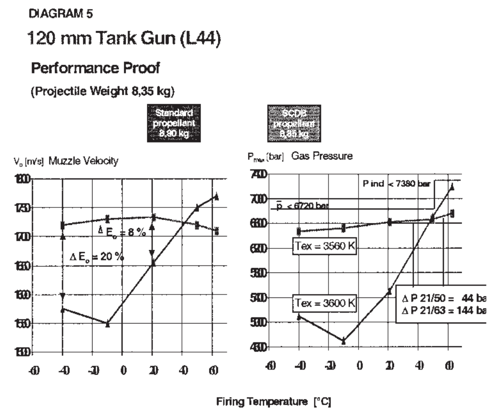
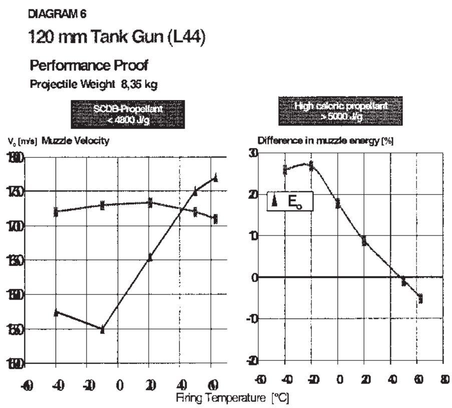




The projectile weight was 8.35 kg. The explosion heat with 4850 J/g was about 150 J/g lower than that of the conventional propellant and the charge weight of 8.85 kg was to load unproblematically.

Concerning the maximum gas pressure and the velocity the propellant shows a nearly temperature independent behaviour.

As demonstrated before, this causes a significant increase of performance in comparison to the in service propellant at temperatures lower than 50°C.

In diagram 6 the difference in muzzle energy between both propellants is demonstrated. Already at 21°C one has an increase of energy of 9%, while at –20°C the advantage is about 27%.

Although the mass of energy of both ammunition types was very similar, this significant increase would only be gained by the special mechanism of the surface coating.

So the exterior ballistic properties can be maintained at a constant level over the whole temperature range.

Propellants with New Energetic Plasticizers

For this special propellant type the normally used blasting oils as DEDGN or NG are replaced by new energetic plasticizers. These propellants show low values for the explosion temperature while the values for the specific energy are comparable to conventional propellants. Therefore one can expect that these propellants may cause relatively low erosion rates.

NC investigated the erosion rates in a special simulator. This is a modified ballistic bomb, where an inset for erosion measurements is adapted.

If during the propellant burning a special pressure value is exceeded, a berst membrane opens, so that the gases leave the closed vessel through the inset, where they can cause a loss of material. This weight loss of the inset is the basis for the assessment of the erosion rate in this system.

Diagram 7 shows some results of one new propellant composition in the erosion simulator. The values of Ja2 and L1/M 2400 are also demonstrated.

DIAGRAM 7

Erosivity of a Propellant with New Energetic Plasticizer

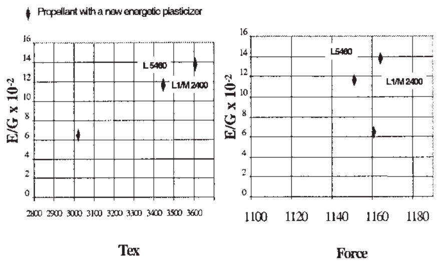
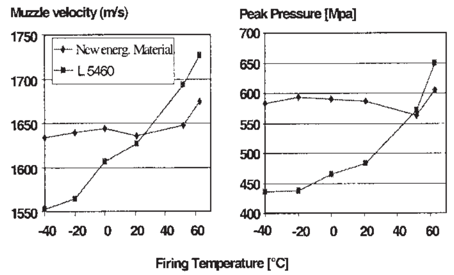


DIAGRAM 8

Propellant with New Energetic Materials
Gun Firing Test in Caliber 120 mm
Type of Barrel L44; Weight of Slug 7,5 kg



The erosion rate is printed out as a function of explosion temperature and force.

Although the new propellant shows a comparable specific energy than L1/M 2400 the erosion rate is nearly bisected. This promising result can be explained by the low explosion temperature of the material.

The first tests for investigating the temperature behaviour of these propellants were done in the ballistic bomb.

Due to some encouraging results in the ballistic bomb the propellant was also fired in a 120 mm ammunition in the barrel type L44 over the whole temperature range from –40 to 63°C. The projectile weight was 7.5 kg.

The results are demonstrated in diagram 8.

As one can see the variations of velocity and pressure with a maximum range of 40 m/s and less than 22 MPa were very small.

This gun firing test was a success and confirmed our closed vessel test results completely.

Therefore one can expect that in comparison to conventional propellants this material may offer a similar potential for an increase of performance than the surface coated material.

The necessary studies concerning safety reproductibility, producibility and investigation of the mechanism will still take some more time before this conception can be transformed and be adapted for special applications.

CONCLUSION AND OUTLOOK

Within the scope of this work during the last years Nitrochemie was able to develop two conceptions for the production of temperature insensitive propellants.

Besides promising results for an optimization of the mechanical stability of the combustible cartridge cases also could be reached which might allow an enlargement of the inner volume of these cartridges in order to be able to increase the charge weights.

With help of these conceptions up to now there could be reached an increase of performance from 10% at normal temperatures to 30 % at deep temperatures compared to propulsion systems with conventional propellants.

By optimization of the charge weight another 5–10% increase of performance can be expected.

Except this one should mention that with a change of the threat in the future also smaller calibers as 90 or 105 mm on mobile vehicles possibly may be used for out of area deployments.

In the USA the Medium Forces are considering the 105 mm caliber, which could be improved in combat efficiency.

In former years surface coated propellants with approved base composition were studied also for the 105 mm ammunition in detail.

Diagram 9 shows test results of surface coated propellants in comparison to M6 in a 105 mm APFSDS-T ammunition with a projectile weight of 5.75 kg.

By exhausting the gas pressure limits here an increase of performance from 7–15% could be reached.

In the Swiss this improved APFSDS-arnmunition was type classified.

Therefore we believe our strategy to be the right one and hope that by combining the here presented steps we will be able to realize attractive improved conceptions for future high kinetic energy ammunition.

DIAGRAM 9

105 mm APFSDS-T

NP 105 A2 / Rohrtyp L 7

Projectile Weight 5.75 kg