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PLASTIC COATED EXPLOSIVES (PCX)

Abstract

EURENCO Bofors has developed and patented a new method for coating explosives with polymers such as polyethylene (PE). The process is efficient and makes less environmental impact than conventional wax coating. It gives a very even coating where every single crystal is coated with a thin layer of polymer. It also allows an even distribution of e.g. graphite on the particle surface.

Polymer coated explosives are free flowing and very easy to handle. They show no signs of exudation while stored under warm conditions. The impact sensitivity is lower than for comparable wax coated explosives, despite less inert material used, which allows a high loading density.

This paper will give an introduction to technique of coating with polymer emulsions and compare HMX, RDX and PETN coated with PE and conventional wax coated products.

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Introduction

Coating is a widely used technique for modifying the characteristics for many explosive substances. Coating technology is e.g. commonly used for physical and chemical protection, to lower the impact and friction sensitivity and to improve handling and press ability [1].

Crystalline high explosives, such as RDX, HMX and PETN are often desensitized by coating particles using wax (1-10% by weight) as coating agent. The wax is either added pure to a dispersion of explosive particles in a liquid (usually water) at a temperature above the melting temperature of the wax or solved in an appropriate solvent. In the first case it solidifies at the surface of the particles when the dispersion is cooled and in the second case when the solvent is evaporated.

Material produced like this is often unevenly coated. The particles are adhered together in lumps and you can even find free crystals of explosives mixed with lumps of wax. Despite that, the coated material often has significantly reduced sensitivity and better pressing properties than the original material.

A more uniform coating can be obtained by using aqueous wax emulsions [2, 3, 4,], but the use of wax still has some disadvantages. By replacing wax with polymers like polyethylene, the risk for exudation if stored under warm conditions will decrease and the product will become more free flowing.

This paper will list some of the advantages with polymer emulsion coating and give a short comparison of some characteristics for HMX, RDX and PETN coated with PE and corresponding conventional wax coated products.

Development

The idea of coating explosives with ionic emulsions was conceptualized at Bofors as early as in 1985. The intention was to get an even coating and also to avoid waxes, which due to their low melting point can cause problems with exudation in the final application if stored warm. The idea was to use emulsions with a surface charge opposite that of the crystals to be coated, which would give a strong adhesion and hopefully also an even coating layer.

However, this concept was not further developed until 2010 when funding was found and a process development project was started. The project description required that the new process should be both economically and environmentally sustainable. Therefore, no solvents should be used, the process should be able to be run at ambient temperature and only commercially available materials were to be used in the development work.

The process development was carried out in a 1 litre double-jacketed reactor equipped with a stirrer. In most of the work low density polyethylene (LDPE) was used for the coating experiments, but also medium density polyethylene (MDPE), high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and polytetrafluoroethylene (PTFE) can be used.

In the experiments, crystals of a high explosives were mixed with water. Stirring was started and a polymer dispersion containing an ionic emulsifier was added. The temperature was adjusted, but only enough to get good viscosity, reduce the surface tension and to increase the conductivity. Thereafter, a dispersion breaking agent was added to make the polymer to precipitate on the crystal surfaces. The precipitation of polymer on the crystal surfaces is caused by ionic attraction, so depending on whether you needed to protonate or deprotonate the emulsifier, an anionic or cationic dispersion breaking agent was used. Finally, the slurry was filtered off, washed with water to get rid of residues and dried.

Finding the right dispersion/dispersion breaker and the right conditions was not easy and many different combinations were tested. The dispersion breaking agent is important, since it affects the conductivity of the mixture and a good conductivity is important to get an even coverage and a good adhesion to the crystal surfaces. It is also important that neither of them affects the characteristics of the explosive in question, acids e.g. could cause reduced stability in the final application. However, with the right combination of dispersions and dispersion breaking agent, the particles became evenly coated with strong adhesion of the polymer to the crystal surface.

With the right combination of dispersion/dispersion breaker it was possible to obtain a very even coating layer, without any tendency of lumps of coating material, see

Figure *1*.

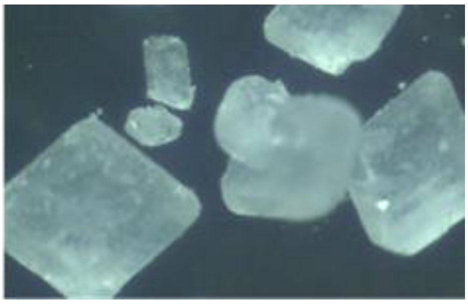

Figure 1: Polymer coated HMX

The first tests with the chosen combination of dispersion/dispersion breaker were carried out with HMX and PETN. The crystals became evenly coated and after drying, they were free flowing and easy to handle. The impact sensitivity were tested by fall hammer and was found to be significantly lower that of conventionally wax phlegmatized material, see Table 1. When pressed, the press density was good; 0.02-0.04 g/cm^3 higher than for comparable wax compositions.

	HMX / wax	**HMX / PE**	**PETN / wax**	**PETN / PE**
Coating mtrl [% w/w]	7	1,5	7	1,5
Fall hammer D50 [cm]	39	74	15-20	36

Table 1: Comparison between particles coated with PE and with wax

The reduced sensitivity can be explained by a more complete coating when using polymer dispersions. Microscopic studies shows that when wax is used, there are often free crystal surfaces together with small lumps of wax, while PE coating gives an even layer of polymer all over the crystals. Except for the even coating layer, coating with polymer emulsions also provides excellent distribution of additives such as graphite or alumina on the crystal surfaces, see Figures 2-4.

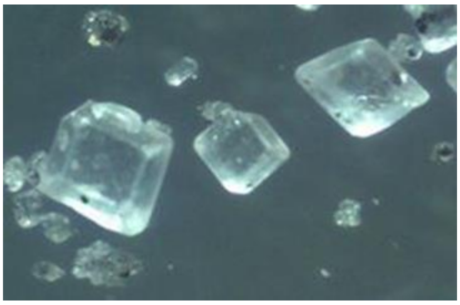

Figure 2 wax 1.2% graphite 0.6%
Pressed density 1.77 g/cm3 at 30 bar HMX

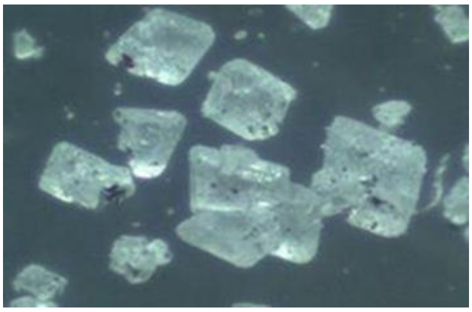

Figure 3HMX, PE 1.2% graphite 0.6%
Pressed density 1.79 g/cm^3 at 30 bar

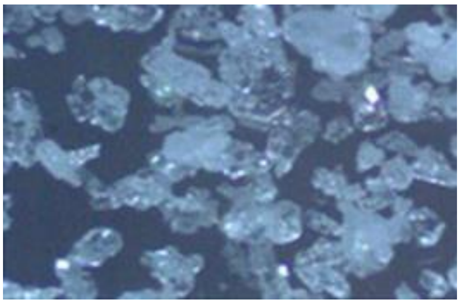

Figure 4 PETN, wax 7% graphite 0.5%

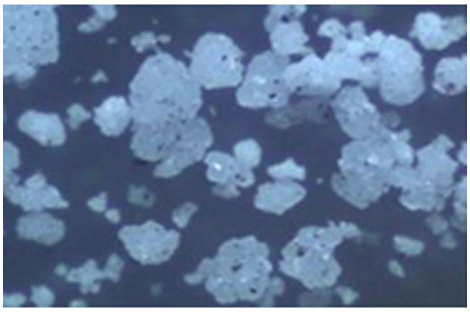

Figure 5 PETN PE 1.5% graphite 0.5%

After the first encouraging results, the technology was further developed to work for more explosives. Today it is proven to work satisfactorily for HMX, RDX, PETN and FOX 7 (see Figures 6-15 below). The coating process was patented in 2015 [5].

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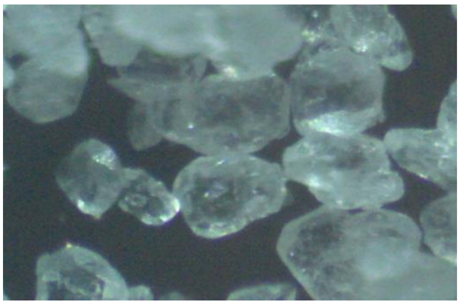

Figure 6 RDX, uncoated

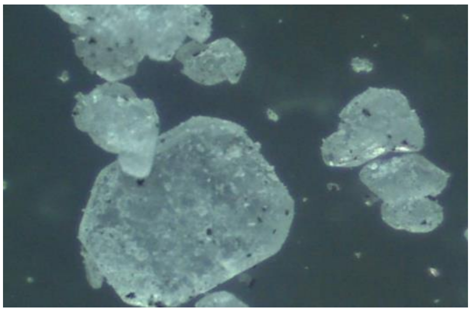

Figure 7 RDX coated with PE and graphite

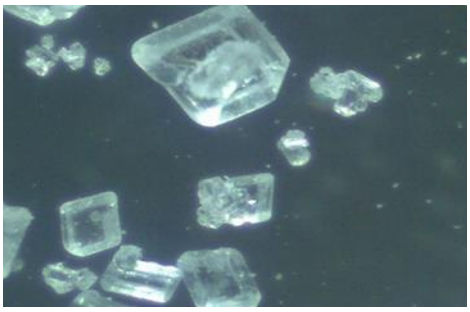

Figure 8 HMX, uncoated

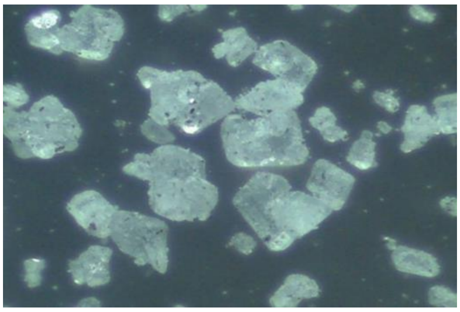

Figure 9 HMX coated with OPE and graphite

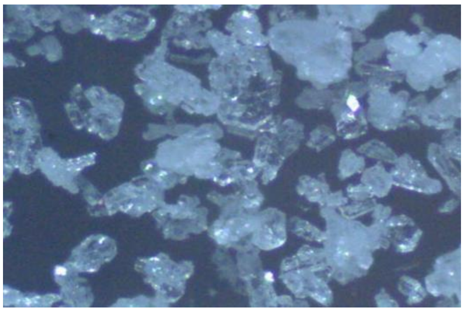

Figure 10 PETN, uncoated

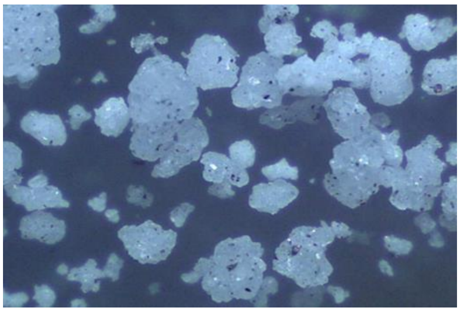

Figure 11 PETN coated with PE and graphite

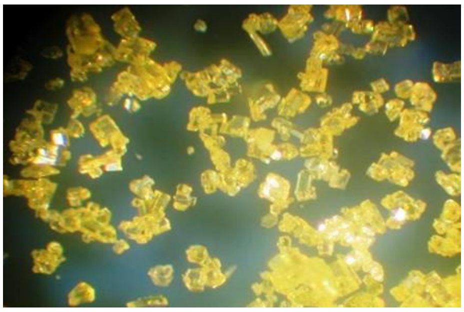

Figure 12 FOX7 uncoated

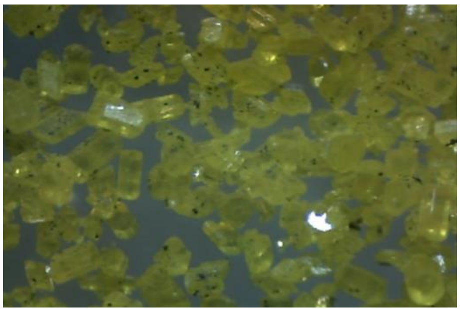

Figure 13 FOX7 coated with PE and graphite

Scale up

The dispersion coating process worked smoothly in lab scale and in 2015 it was ready to be scaled up to production scale. Scale-up was made directly from litre-scale up to 500 kg batches without any problems or drawbacks whatsoever. Today, the process works fast and smooth and can if needed, easily be further up-scaled. The manufactured crystals have uniform and high quality coating. The working environment has been improved in the production plant, since no solvents is used in the process and the low process temperatures reduces the occurrence of vapors and odors.

Sensitivity testing

PE-coated particles of HMX, RDX and PETN were tested for friction, impact and electrostatic discharge sensitivity according to Swedish Defense Standard FSD 0214 by Saab Dynamics AB. GAP-tests were carried by EURENCO Bofors. For comparison, also corresponding wax coated compositions were tested in the same way.

All compositions used for the tests were produced in the regular production facility at EURENCO Bofors, Sweden.

According to the test results:

- Friction sensitivity according to BAM friction apparatus for the PE-coated HMX and RDX shall be classified as moderate, while it for wax coated product shall be classified as high For PETN, both PE-coated and wax coated product the sensitivity is classified as high.
- Impact sensitivity according to BAM fall hammer for PE-coated HMX and RDX shall be classified as medium, while it for wax coated product shall be classified as high. For PETN, both PE-coated and wax coated product the sensitivity is classified as high.
- Ignitability at electrostatic spark is classified as low sensitive for both PE-coated and wax coated HMX, RDX and PETN.

Even if the impact sensitivity for PE-coated PETN still is classified as high, our tests show that fall hammer height is almost doubled compared to that for wax-coated. Together with the improved handling properties and the fact that there is no risk for exudation under warm condition, something that in worst case could make the booster not function, that has made polymer coated PETN a popular product among our customers, mainly in the oil and gas and in the mining industries, where PCXs are used for electrical and non-electrical detonators, detonating cords, for ignition and for main charge in shaped charges for perforating guns in deep well completion and for booster charges.

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Summary and conclusions

EURENCO has developed and patented a process for coating particles of high explosives with polymers using ionic emulsions. This technique gives even coating and strong adhesion of coating material on the crystal surfaces. It also provides excellent distribution of additives such as graphite on the crystals. The process is scaled up and plastic coated explosives (PCXs) are manufactured in full production scale. Today PCXs are standard products in the EURENCO product catalogue.

Polymer coated products can be used for detonators, detonating cords, for ignition, for booster charges and for main charge in shaped charges for perforating guns in deep well completion. They are free flowing and have high press density. So far, the users are mainly to be found in the oil and gas industry and in the mining industry. However, plastic coated explosives ought to be of interest also for military applications, due to the many advantages plastic coating has compared to conventional wax coating:

- More uniform coating of the individual particles
- Improved adhesion of coating material
- Even distribution of additives such as carbon or alumina
- Reduced impacts and friction sensitivity
- No exudation during storage at elevated temperatures
- Free flowing particles with good loading and pressing properties
- Increased press density
- Improved electrostatic properties
- Less environmental impact (no solvents and no heating needed in the production process)

References

[1] H. Schmid, Journal of Hazardous Materials, Vol. 13, Issue 1, p89-101
[2] British Pat. No. 574,271
[3] U.S. Pat. No. 3,740,278
[4] U.S. Pat. No. 3,544,360
[5] Swedish Pat. SE 537770 C2

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