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# THE ROLE OF POLYMER BINDERS IN THE MANUFACTURE OF PYROTECHNIC COMPOSITIONS

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**Abstract.** Modern pyrotechnics is a part of applied chemistry and deals with the preparation and study of various chemical substances and compositions that form wind fires and smoke when burned, as well as producing incendiary and illuminating effects or creating sound effects.

Fire signalling in military affairs to date has a wide application (negotiation by means of flashes in Mor-ze alphabet, signalling by coloured lights, etc.). But, mainly, the development of military pyrotechnics went along the way of studying and using incendiary substances.

Pyrotechnic means should not be dangerous when handling and storage. The effect they produce must not deteriorate after prolonged storage.

Materials used for manufacturing of pyrotechnic means should be as non-deficient as possible. The technological process of manufacturing should be simple, safe and allowing mechanisation and automation of production.

The main purpose of this work is to review polymeric binders used in the manufacture of pyrotechnic mixtures and to identify new ways of their use.

**Key words:** polymer binders, iditol, coniferous trees, pyrotechnic compositions, resinates.

**Анотація**. Сучасна піротехніка є частиною прикладної хімії і займається одержанням і дослідженням різноманітних хімічних речовин і складів, які при згорянні утворюють вітряний вогонь і дим, а також створюють запальні та світлові ефекти або створюють звукові ефекти.

Пожежна сигналізація у військовій справі на сьогоднішній день має широке застосування (перемова за допомогою спалахів азбукою Морзе, сигналізація кольоровими вогнями та ін.). Але, в основному, розвиток військової піротехніки йшов по шляху вивчення і використання запалювальних речовин.

Піротехнічні засоби не повинні становити небезпеки при транспортуванні та зберіганні. Вироблений ними ефект не повинен погіршуватися після тривалого зберігання.

Матеріали, які використовуються для виготовлення піротехнічних засобів, повинні бути максимально недефіцитними. Технологічний процес виготовлення повинен бути простим, безпечним і допускати механізацію і автоматизацію виробництва.

Основною метою даної роботи є огляд полімерних в'яжучих речовин, які використовуються у виробництві піротехнічних сумішей, та визначення нових шляхів їх використання.

**Ключові слова:** полімерні в'яжучі, ідитол, хвойні породи дерев, піротехнічні склади, резинати.

Products made of pyrotechnic compositions (draughts, flares) must have sufficient mechanical strength to meet the requirements of operation.

When developing new compositions it is necessary in each individual case to carefully consider the choice of combustible and oxidising agent and to calculate quantitative ratios between them, at the same time it is necessary to take into account their physical and chemical properties.

The development of formulations is also complicated by the fact that in most cases other components have to be added to the double mixture (oxidiser-fuel) in order to fulfil all requirements.

It is not always possible or advisable to achieve high strength of compounds by applying high pressing pressures alone. In order to increase the strength of the product, binders (sometimes called cementing agents) are added to the compositions. Artificial and natural resins, rubber and other organic substances are used as binders.

In some cases, the introduction of binders is intended to give the necessary strength to grain compositions; in this case, the necessary strength of grains (granules) must be ensured during transport, storage and action of the product.

One of the methods of testing the strength of products is to determine the force required to destroy a test cylinder (star) of pyrotechnic composition.

The test sample of the composition (usually a checker with a diameter of 20 mm and height of 30 mm) is placed between two small steel plates, and slowly, at a constant rate of convergence of these plates, find the force required to destroy the checker.

With the help of testing machines, the fracture force of the bead is accurately determined, constant test conditions are ensured and, above all, a constant rate of increase of the load is ensured.

Factors affecting strength

The strength of the compressed product depends on:

1) on the properties of the basic oxidiser-fuel mixture;

2) on the properties of the binder and its quantity in the composition;

3) on the degree of grinding of the components;

4) on the way the binder is introduced into the composition: dry, in the form of a solution (varnish), solution concentration;

5) the specific pressure of pressing and the time of holding under pressure;

6) from the height of the simultaneously compacted portion of the composition and the ratio between height and diameter.

Compositions of components with higher hardness are poorly compacted, and often products made of them have low strength.

The strength of the product increases with increasing pressing pressure, but usually does not exceed 20-25 % of the specific pressing pressure [1].

The most frequently used binders are:

- artificial resins - iditol, bakelite, epoxy resins, etc.;
- resins of natural origin and products of their processing: caniphol, resinates;
- drying oils - olive oil;
- glue - dextrin.

In addition, it is possible to use various asphalts and bitumens: In some cases, solutions of nitrocellulose and rubber in the appropriate solvents. For nitrocellulose the solvent can be alcohol-ether mixture, acetone, for rubber benzene, benzene, etc., and in solid pyrotechnic fuel the solvent can be alcohol-ether mixture, acetone [2].

In solid pyrotechnic fuels polyurethanes, thiokol, rubbers are used as binders.

Characteristic properties of resins are:

- insolubility in water;
- solubility in organic solvents;
- ability to form a film when the resin solution dries;
- resistance to decay (unlike adhesives of animal origin).

A frequently used binder is iditol, which is a "new-lacquer" resin obtained by condensation of excess phenol with formaldehyde in the presence of an acidic catalyst (e.g. HCI).

The reaction in the initial stage proceeds as follows:

$$CH_2O + 2C_6H_5OH = CH_2(C_6H_4OH)_2 + H_2O$$

The product of the primary condensation, polymerising, turns into a resin when heated. The conditional formula $C_{13}H_{12}O_2$, is used in calculations for iditol. Iditol is well soluble in ethyl alcohol.

Novolac resins are well soluble in alcohols, insoluble in hydrocarbons and mineral oils. They are resistant to water, acids, ammonia and weak alkali solutions. Strong alkali solution decomposes them. Technical samples of iditol always contain free phenol, which explains their reddish colour.

For iditol the softening temperature is standardised (for different grades not lower than 90-97 °C, its phenol content from 0.1 to 3.0 % and the absence of rosin is tested. One of the binders, rosin, is obtained from the resins of coniferous trees [3].

Its main constituents are unsaturated cyclic acids - abietinic and pimaric acids. The density of rosin is 1.0-1.1 g/cm$^2$; softening temperature is not lower than 65 °C. Rosin is soluble in ethyl alcohol, ether, benzene, partially in petrol; when heated, it dissolves in olive oil.

Resinates are products of interaction of rosin with hydroxides or salts of corresponding metals. Calcium resinate is obtained by fusing rosin with slaked lime at a temperature of 230-240 °C. However, this reaction does not proceed to the reaction.

However, this reaction does not proceed to the end, calcium resinate is characterised by a certain acid number (not more than 80), however, much less than for rosin 160-180. Softening temperature of calcium resinate is 120-150 °C. Its composition can be approximated by the formula $(C_{19}H_{29}COO)_2Ca$.

As solvents for calcium resinate are used petrol or alcohol-benzine mixture (1:1).

It is also possible to use strontium resinate when red colouring of the flame is required.

Sometimes monomers are used in pyrotechnic compositions, which after polymerisation become binders: methyl methacrylate, vinyl dichloride, styrene, acrylonitrile, vinyl acetate.

## Conclusion

The role of polymeric binders in the manufacturing process of pyrotechnic compositions is extremely important and multifaceted. Polymeric binders allow achieving high stability and safety of pyrotechnic products, ensuring their efficiency and reliability in operation. These materials make it possible to create a variety of shapes and consistencies of pyrotechnic compositions, which opens up wide opportunities for their use in various industries, from entertainment to military equipment. In addition, the use of polymeric binders can improve the environmental safety of pyrotechnic compositions, reducing the risk of environmental pollution. Thus, it can be concluded that polymeric binders are a key element in the production of pyrotechnic compositions, contributing to the improvement of their quality, safety and functionality.

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