Practical Aspects on Using Polytetrafluorethylene (PTFE) in Pyrotechnic Compositions

SIMION NACU*
National Administration “Romanian Waters”, Somes-Tisa Water Branch, Management System of Waters from Maramures county, 2 Aleea Hortensiei Str.,430294, Baia Mare, Romania

Polytetrafluorethylene PTFE is used in flare pyrotechnical compositions, together with a metallic fuel, usually magnesium or aluminum plus a binder. This paper presents new research on the flare pyrotechnical compositions for thermal decoys, obtained from polytetrafluorethylene (PTFE), carburants like aluminum or magnesium, phenol-formaldehyde resine and graphite. DTA differential thermal analysis is used to determine the thermal behaviour of energetic material and the auto-inflammation temperature. For performance characteristic of pyrotechnic compositions, the combustion velocity has been determined.

Keywords: PTFE, decoy, pyrotechnical composition, differential thermal analysis (DTA)

The goal of this research is a theoretical and experimental study of producing pyrotechnical compositions based on polytetrafluorethylene (PTFE), magnesium, phenol-formaldehide resine and graphite, followed by the testing of their physical, chemical and explosive properties and potential applications.

Polytetrafluorethylene (PTFE) is a fluorurated polymer with a molecular weight between 10000 and 100000. The special properties of PTFE are mainly due to its structure, high intermolecular forces and molecular symmetry [1].

Advantageous properties, making PTFE a valuable material are: the good thermal stability in a wide temperature range (-250 to 260^{0}C), chemical inertia towards most chemical agents, low friction coefficient, very good abrasive resistance, anti-adherence characteristics, good dielectric properties, endurance against UV and nuclear radiations. The melting point is 327^{0}C but partial degradations start at 260^{0}C.

Some of polytetrafluorethylene disadvantages are: high density 2.1-2.2 g/cm^3, high dilatation and contraction coefficient, high price. Polytetrafluorethylene processing technologies are similar to those applied to metallic powders comprising the following steps: pre-forming at ambient temperature and pressure, sintering at high temperatures (about 370^{0}C) and cooling [1].

Polytetrafluorethylene is delivered as a white powder or with the addition of some plasticizers, as waxes, oils or resins of different viscosities or as copolymers. Polytetrafluorethylene is a good fluorine source, as it contains 75% fluorine, and during decomposition it strongly attacks the metals through an exothermic reaction [2].

Another pyrotechnical compositions were reported in [3-9].

Experimental part

In order to predict the performance characteristics of a decoy pyrotechnic composition, the combustion reaction and some thermodynamic parameters (heat of combustion, combustion temperature, chemical composition of reaction products, specific volume etc.) need to be evaluated.

When heated over 350^{0}C polytetrafluorethylene decomposes with fluorine elimination that reacts violently with magnesium, aluminum, titanium forming metallic fluorides.

$$Mg + (C_2F_4)_n = 2n\ MgF_{2\,(s)} + 2nC \quad \Delta H = -1438 \text{ kJ/mol}$$

The high amount of heat is due to the fact that magnesium fluoride has a high heat of formation (–1124 kJ/mol [2]).

Based on former research [2], the following decoy pyrotechnic mixture was proposed: PTFE 51.5%, Mg 40%, phenol-formaldehyde resin 7.5%, graphite 1%.

The experimental research was necessary to demonstrate the safety and performance characteristics of news pyrotechnic compositions. In this paper are presented only some results: velocity and thermal behavior (Differential Thermal Analysis) of combustion reaction.

The pyrotechnic compositions subject to the experimental studies are presented in table 1.

Combustion velocity

The combustion velocity represents the speed of energy release or the speed of reactants consumption in time [9].

The pyrotechnic effect is closely related to the combustion velocity and the time combustion. The propagation of combustion reaction has to be as homogenous as possible and the global unit characterizing the propagation process is the combustion velocity.

An important performance characteristic of a pyrotechnical system is the operational time. If we know the combustion thickness of each layer or of the whole pyrotechnical load are, we can determine the combustion time if we know the combustion velocity. After the composition ignition, combustion process takes place rapidly with the appearance of a “reaction zone” in which the reactive compounds is transformed into solid, liquid and gas combustion products. These ones can escape the area or are immobilized. The reaction zone moves towards the un-reacted composition area with a speed named combustion velocity [9].

Combustion velocity can be defined as Linear combustion velocity: $u = \Delta x / \Delta t$ mm/s .

For experiments were used the following equipment and materials:apparatus for combustion velocity

* email: nacusimion@yahoo.com

Table 1
CHEMICAL COMPOSITION (%) FOR EXPERIMENTAL DECOYS PYROTECHNICAL COMPOSITIONS

Component	PTFE	Mg	Ti	Al	Al-Mg Alloy	Binder	C
CAP-1	56.5	34	-	-	-	9.5	-
CAP-2	56.5	34	-	-	-	8.5	1
CAP-3	70	-	-	24	-	6	-
CAP-5	64	-	30	-	-	6	-
CAP-6	64	-	-	-	30	6	-

determination; weighting glass; analytical scales; slide rule; adhesive paper; star fire fuse; ignition source (lighter); chronometer; Sony photo camera.

Pyrotechnical compositions in compressed state are prepared as follows: the tube for pressing operation is selected; the dimensions of the tube are computed; the dose of the load is chosen, that by pressing leads to a thickness of combustion height of 1-2 diameters; the amount for the pyrotechnical composition is weighted and placed into the tube; the mixture is pressed with a hydraulic press until it reaches a certain pressure in order to achieve an average combustion speed (density of charge) at least 3 tests of these load conditions are recommended; ignition material is placed inside the tube, which may be up to 10% of the total mass and a wick ignition relay, used for achieving a pyrotechnic delay for the manual ignition of the mixture; all the necessary information are filled in the test report. All the means for measuring the combustion time are prepared (combustion time chronometer, film cameras); pyrotechnical composition is manually ignited.

Before the test the materials used for ignition are prepared. Supplementary ignition mixture will be determined so that the mass be sufficient for the safety ignition of the material.

To ignite the supplementary relay an incandescent filament is used, or delay relay (some start fire fuse). The relay should be 3-4 cm ensuring 3-4 s delay.

The start fire fuse is inserted into the pyrotechnic mixture, in the area where the supplementary ignition mixture is located, fixed with a piece of adhesive paper.

Environmental conditions may influence the results of the experiments. In order to limit these influences the tests are carried out at: temperatures between 10 and 30 ^{0}C and relative humidity between 40 and 70 %.

Combustion velocity of pyrotechnical mixture is determined by chronometrical method. It is based on time measurement of the combustion for the pyrotechnic charge with specific height. The linear combustion velocity is obtained from height divided by the time. Time has been measured manually with chronometer because the values were from seconds to tens of seconds.

Two tests have been performed using a pyrotechnic charge of 10.5 mm diameter. Pressing took place at 5 bar for the first test and 10 bar for the second. After pressing, 2 fuse relays were inserted and height of the charge has been measured.

Computation combustion velocity: u_1 = 1.173 mm/s (t_1=9.7 s, Δx_1=11.38 mm) and u_2 =1.139 mm/s (t_2=7.3s. Δx_2=8.31 mm)

t_1= 9.7 s; h=11.38 mm; v_1=1.173 mm/s; t_2=7.3s; h=8.31 mm; v_2=1.138 mm/s

Differential thermal analysis (DTA)

For safety and performance reasons it is important to know the thermal characteristics of explosive materials.

This method is used to measure the thermal sensitivity of pyrotechnical composition. Differential thermal analysis records the temperature difference between a substance and an inert reference material when heated simultaneously.

The tests have been performed using a differential thermal analyzer - OZM 551 designed for heat rate of 5 and 20^{0}C/min, with automatic recording of temperature difference between the sample and the reference material.

The test tubes used during these experiments are manufactured from thermally inert materials as compared to the sample. The reference materials have also to be inert with no thermal activity in the temperature domain . For most of applications, alumina or glass proved to be sufficient. An analytic scale with a precision domain of one tenth of milligram is used to weight the samples.

-The explosive sample is weighted and put into the test tube which is inserted into the apparatus.

- Heavy software is initialized and experimental parameters are set.

- Heating program is used.

- Sample heating is controlled so that the heating increasing is constant until the maximum is reached.

- The data and the thermograph are automatically stored into a file.

- Once the heating bath is cooled at room temperature another test can be started.

Below are presented some experimental results for decoys PTFE pyrotechnic compositions (their chemical compositions are presented in table 1).

Results and discussions

As we can see in figure 1, the presence of PTFE decides the thermal behaviour of all pyrotechnic compositions. Even for more reactive metals, the auto inflammation temperature is near 480 ^{0}C and the heating resistance is very high.

The endothermic transformation at 330 – 340 ^{0}C shows the melting process for PTFE.

Another endothermic transformation is presented for CAP-6 composition at 450 – 460 ^{0}C temperatures. The origin of this transformation is probably connected with melting of Al-Mg alloy, or other endothermic event.

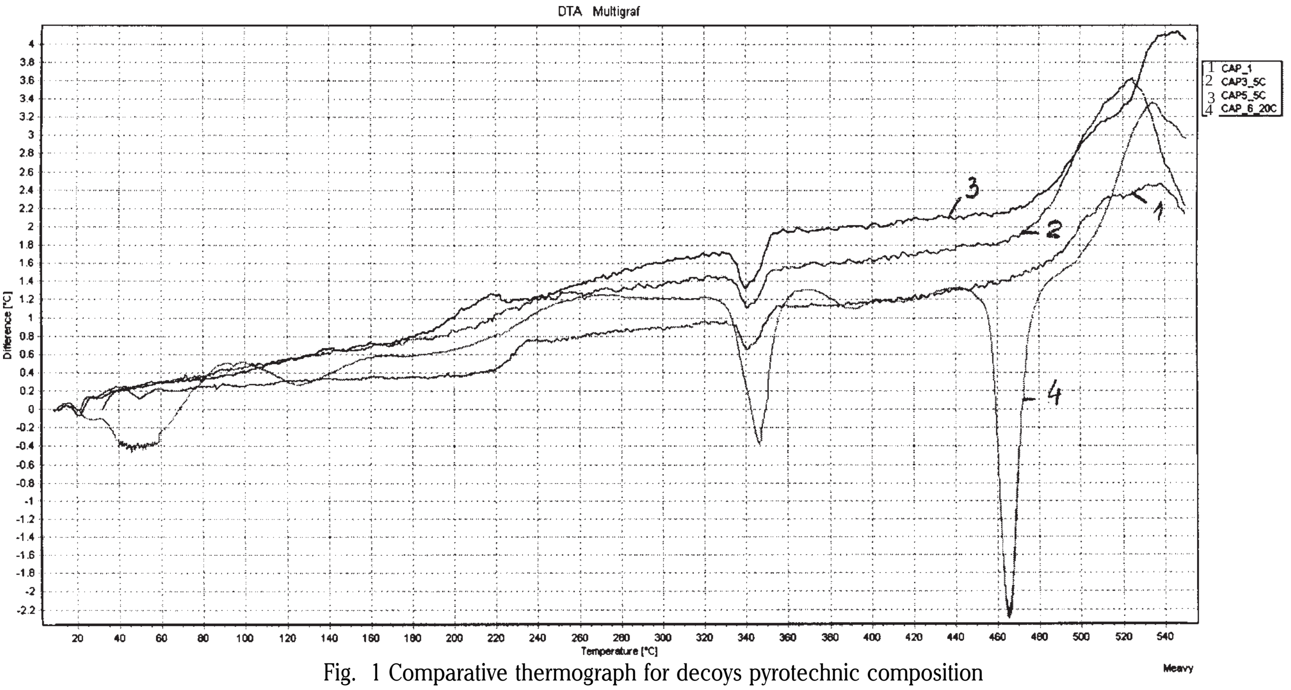

Fig. 1 Comparative thermograph for decoys pyrotechnic composition

Conclusions

The decoys pyrotechnic compositions are relatively simple to manufacture. Important is to design o good chemical composition in order to obtain the safety and performance characteristics.

Using phenol-formaldehide resin as a binder guarantees the constancy of its properties.

The experimental results shows a high thermal resistance, and the ignition temperature is situated near 470 ^{0}C.

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