New stabilizers for NC-propellants Evaluated in Rocket Propellants

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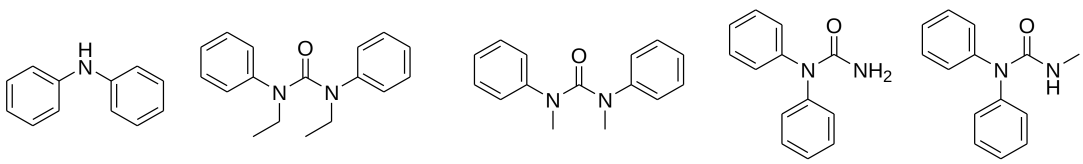
Abstract:

Over the last few years Eurenco Bofors in collaboration with FOI has developed new stabilizers, which are anticipated to generate less toxic degradation products. Earlier work developed several compounds, which were investigated and showed stabilizing properties both for pure nitrocellulose, and nitroglycerine and nitrocellulose mixtures. In the continuation of this work Stab-5 and Vitamin A were used as stabilizers in rocket motor propellant to investigate how they affect the burning rate characteristics of a propellant. Also the stabilizing properties are investigated in this typical propellant composition of nitrocellulose, nitroglycerine, plasticizer and ballistic modifiers.

Keywords: Stabilizer; Stab-5;Vitamin A; Nitrocellulose; Propellant; Rocket Motor propellant; Double base

Introduction

Stabilizers are used in nitrocellulose (NC) containing propellants to post-pone the autocatalytic process, which occurs when NC is decomposing[1]. The common stabilizers used in NC containing propellants today are all prone to form N-nitrosoamines when the stabilizer is reacting with decomposition products from the propellant. Due to the health aspects of these N-nitrosoamines[2], Eurenco Bofors together with FOI have worked in the development of alternative stabilizers, which do not contain any aromatic amine motif.



Diphenylamine **Centralite I** **Centralite II** **Akardite I** **Akardite II**

Figure 1 Chemical structure of stabilizers commonly used today.

Several promising alternative stabilizers were identified during the earlier studies in this project. Especially for a new type of stabilizers based on Syringol, the bis-(2,6-dimethoxyphenol) triethylene glycol ether, also referred to as Stab-5[3,4] good results were obtained. The recent work of identification of the degradation products of propellant stabilized with Stab-5 verify that the degradation products are anticipated to have a beneficial toxicity profile[5] compared to the stabilizers used today.

In this study the identified potential new stabilizers Stab-5 and Vitamin A were investigated. Also Akardite II and Centralite I were used as reference in the experiments. The Stab-5 used was produced by FOI in their scale-up study[6]. The stabilizers have been evaluated in a double base rocket motor propellant. The composition is approximately 48.5 weight-% of nitrocellulose (NC), 44 weight-% of nitroglycerine (NG), 2.5% plasticizer, 2.5% stabilizer and 2.5% of ballistic modifiers.

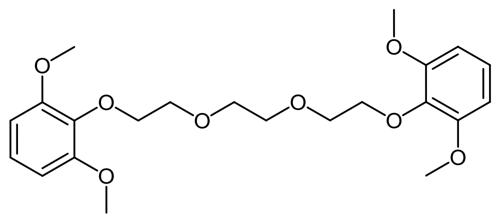


Figure 2 Stab-5 (bis-(2,6-dimethoxyphenol) triethylene glycol ether), a new promising stabilizer.

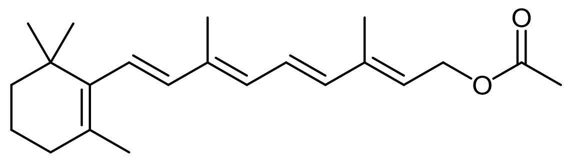


Figure 3 Chemical structure of retinyl acteate, also known as vitamin A acetate, a promising stabilizer.

For this rocket propellant Centralite I is the stabilizer used today. Due to environmental and health regulations, the Centralite I must be substituted for the future production of this propellant. This is the reason why this composition was chosen for the test series, but the composition is also typical for double base rocket motor propellants produced by Eurenco Bofors. This is the first test series performed with Stab-5 for a commercially produced double base composition. A rocket propellant was chosen due to the sensitive nature of the burning characteristics in this type of propellant. For best performance in the final application, the rocket motor propellant should exhibit a constant burning rate over the pressure range which the weapon system is designed for. One of the goals for this study was to investigate if the stabilizers alter the burning characteristics of a double base propellant.

Experimental method

In the formulation and production of the test series one batch of 100 kg homogenous paste mix was used. The NC, NG, and plasticizer are premixed, in a wet process, in the Eurenco Bofors nitroglycerine plant and then the ballistic modifiers and other additives are added in a second, dry, mixing step. In the work of this study, the stabilizer was added in a smaller mixer together with the paste mix and mixed for 30 minutes to ensure a homogenous mix. This methodology ensured that the only difference between the samples produced was the type of stabilizer added. The batch size of the small mixer is 9 kg and one batch of each stabilizer was produced.

The next step in the process of producing the test samples was identical for all stabilizers and consisted of differential roll milling and ram extrusion. The batches for rolling is 3 kg of dry weight and for extrusion approximately 2 kg, hence each stabilizer batch was divided in 3 rolling batches and 4 extrusion batches. The extruded propellant was in the form of single-perf strands with a 30 mm outside diameter and 15 mm inside diameter. The strands were cut into 100 mm long cylinders. These are called standard rockets.

Figure 4 Picture of a standard rocket produced in this study.

Standard rockets from each sample were fired in the ballistic laboratory in a rocket motor model. In order to evaluate the burning rate at a range of pressures the nozzle was varied in a range from 10.1 to 6.3 mm, generating propellant area ratios shown in Figure 5. It should be observed that the ratio values are the initial values and not the average. The average is slightly smaller because the standard rockets are not inhibited and burns from all sides. The burning distance is around 4 millimeters.

The standard rockets were evaluated first directly after being extruded and then after a three weeks storage at 70 °C to simulate ageing. This procedure is used to evaluate the long term stability of the ballistic properties for the composition.

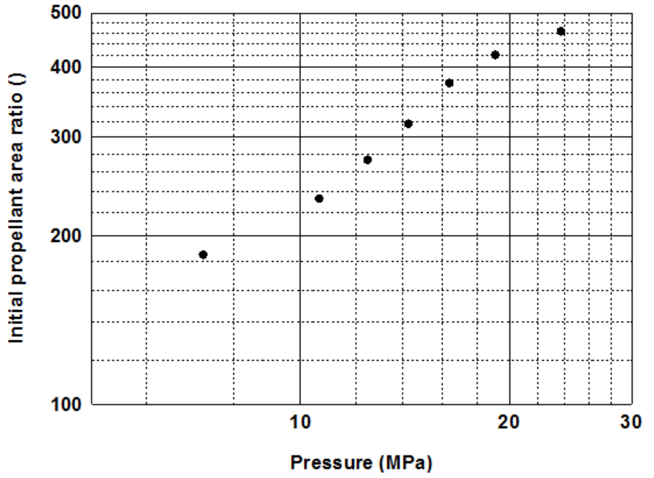


Figure 5 Initial propellant area ratio (burning surface over nozzle area) versus average pressure.

Results

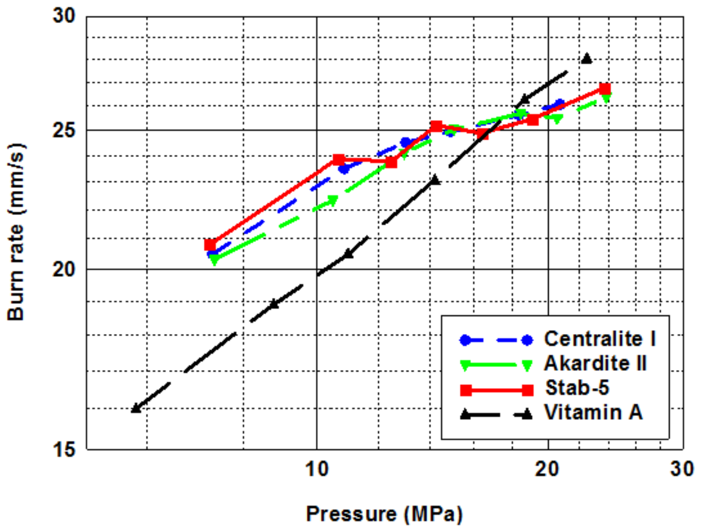


Figure 6 Burn rate vs. pressure for the four compositions in the study.

The results for Stab-5, Vitamin A, and the two references Akardite II and Centralite I are visualized in Figure 6. From the results it is seen that the burning behavior of Centralite I and Akardite II are very similar, since the molecules are very similar this is not very surprising. Also the results for the Stab-5 are good in the sense that the burning characteristic includes a plateau behavior around 15 – 25 MPa, the overall burn rate is slightly higher compared to the references especially at lower pressure. The Vitamin A results on the other hand show that the burning characteristics are altered significantly, the pressure coefficient is constant for this stabilizer throughout the investigated pressure range.

The Stab-5 samples were also investigated after a three week conditioning in 70 °C.The firing results for Stab-5 before and after conditioning is shown in Figure 7. The firing after the simulated ageing does not indicate any significant change in ballistic behavior.

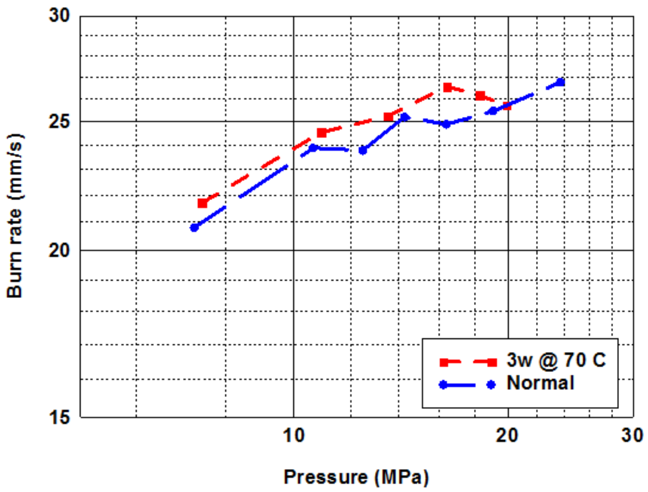


Figure 7 Burn rate vs. pressure for the Stab-5 sample, before and after simulated ageing.

The thermal stability of the four propellants was evaluated at FOI according to STANAG 4582 at 75°C for 19 days. All of the propellants passed the STANAG test successfully.

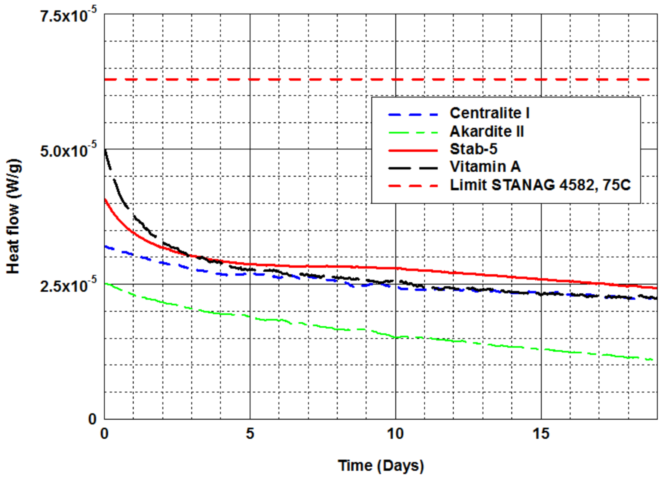


Figure 8 Heat flow measurements according to STANAG 4582 at 75°C

Conclusions

These initial tests indicate that Stab-5 would be a suitable stabilizer in double base rocket motor propellants. The burning characteristics are altered slightly but not in any significant way. This alteration can easily be adjusted with the ballistic modifier or overall calorific value of the propellant. For both the thermal and ballistic stability Stab-5 show no indication of negative effects.

For Vitamin A, there is a clear indication that it is problematic to use in a double base rocket propellant. The burning characteristics are altered significantly and the plateau behavior is removed. The thermal stability is still good for the Vitamin A in this composition though.

Next step in the investigation of Stab-5 is to evaluate the mechanical properties of rocket motor propellants containing Stab-5.

Also this study confirms that a switch between Centralite I and Akardite II as stabilizer will not modify the burning characteristics in any significant way. And the thermal stability is good for these two stabilizers.

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