Tribological Conditions leading to the Ignition of an Energetic Material

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1. Introduction

By definition, energetic materials can deliver a huge amount of hot gas and cause different kinds of phenomena, such as: burning, deflagration or detonation. Those materials are used in different fields, such as the automotive industry (airbag deployment), military devices (missiles, ammunition) and space launchers (Ariane 5 boosters and pyrotechnic devices). The manufacturing process, although well controlled by the historical "batch" process, presents several challenges when it is transferred to the continuous mixing process, using a twin-screw mixer device. Indeed, this last induces extreme evolutions of pressure gradients and shearing gradients (reduced air-gap...). Consequently, tribological conditions leading to the ignition of an energetic material, a solid propellant, are studied during its manufacturing in a twin-screw mixer.

2. Experimentation and after-test analysis

In order to reproduce the mechanic stresses undergone by the solid propellant during its manufacturing in a twin-screw mixer (compression and shearing), a linear tribometer is chosen: the TriboME device, **Fig.1**. This last is resulting from normalised device instrumentation, allowing to realize the Friction Test of energetic materials (Julius Peters device) **[1]**. During the test (t=300ms), the normal stress (F_Z) is applied by a sapphire pin, and the tangential stress (F_Y) is measured via an instrumented steel plate, on which a sample of solid propellant is laid.

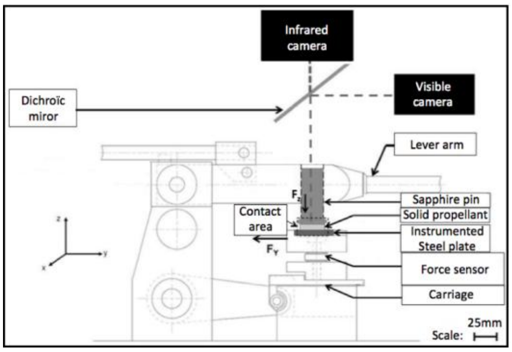

Figure 1: TriboME device

Through the sapphire pin, the contact surface is simultaneously observed in visible and infrared domains by high-speed recording cameras. In this way, localised reactions (hot spots) **[2]**, generalised reactions (solid propellant ignition) and rearrangements of components **[3]** are visualised.

These rearrangements of components, within the solid propellant, are post-mortem analysis (optical and scanning electron microscopies). It depends on mechanical and physicochemical properties of components (relative solubility, solid components geometry...). These rearrangements are characterised by the morphology evolution of the solid propellant, and are called segregations. Different types of segregations take place during the friction test, and are gone along with superficial cracking on the contact surface **Fig.2**.

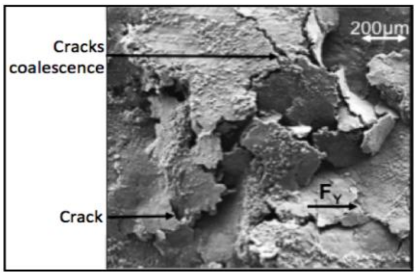

Figure 2: Observation of the solid propellant contact surface, after the friction test, by Scanning Electron Microscopy

3. Summary

The TriboME device instrumentation (force and displacement sensors, "infrared and visible" high-speed recording cameras) coupled to after-test analysis of the contact surface thanks to optical and scanning electron microscopies, allow to identify several types of components segregations within the solid propellant. These segregations favour interactions between components (solid/solid shocks, redox reactions...), which lead to localised ignitions called hot spots **[2]**, and/or generalised ignitions of the solid propellant. Segregations and interactions could be encountered in reduced air-gaps of a twin-screw mixer, whence risks of solid propellant ignition. Risks to be avoided!

4. References

[1] Norme NF T 70-503 : « Epreuve de sensibilité au frottement », SNPE Matériaux Energétiques.

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