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Abstract #
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Corresponding author: DECKER Thomas
e-mail of corresponding author: thomas.decker@onera.fr
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Title

Agglomeration in solid propellants loaded with inert particles – Study of propellant formulation influence using Shadowgraphy Image Processing

Authors

Thomas DECKER [1], Robin DEVILLERS [1], Stany GALLIER [2]*

** Corresponding author*
[1] ONERA, 6 Chemin de la Vauve en grange, 91120 Palaiseau, France, thomas.decker@onera.fr, robin.devillers@onera.fr
[2] ArianeGroup SAS, 91710 Vert-le-Petit, France, stany.gallier@ariane.group

Abstract

Solid Rocket Motors (SRM) are now widely used in both civilian and military applications in propulsion. Most composite solid propellant compositions used in space applications include oxidizing particles in a binder. Adding metal particles such as aluminum can increase propulsion performance, in the range of 10%. The initial aluminum particles can agglomerate on propellant surface to form larger droplets. The droplets then interfere with the gas flow within the combustion chamber. This directly impacts performance and instabilities, such as two-phase losses, hydrodynamic instabilities [1], thermoacoustic instabilities, incomplete combustion, formation of alumina slags, nozzle erosion and plume signature. All those phenomenon depends strongly on the initial aluminum droplet size, hence agglomeration.

Aluminum agglomerate size is mainly determined using empirical correlations or geometrical considerations, such as pocket models. The methods are moderately predictive and only yield mean diameters. The development of predictive models requires the understanding of the physical phenomena associated to agglomeration.
While studies mainly focus on aluminum agglomeration, phenomena leading to larger structures (aggregates) are also observed with inert particles such as titanium dioxide TiO_2 or magnesium oxide MgO [2]. Agglomeration of inert particles is easier to study because they do not burn, hence they keep their initial size and do not generate smoke, that is detrimental to image quality. Image processing used to study agglomeration is then easier to develop. New image processing tools have been developed in order to detect agglomeration patterns on a solid propellant surface [3]. The new algorithms have been applied to images of a solid propellant loaded with inert particles burning at different pressures. Physical parameters associated to particles agglomeration have been calculated at different pressures such as residence time, aggregates size and acceleration in the gas flow [4].

The study presented here focuses on the influence of the solid propellant formulation on the agglomeration of inert particles. Three propellants containing different AP (Ammonium Perchlorate) size repartitions are studied: they all contain the same proportion of HTPB binder and inert particles (42 μm ceramic particles loaded at 10% in mass). Images were acquired using a shadowgraphy set-up with a high-speed acquisition of 7.5 kHz. The combustion chamber is pressurized with pure nitrogen with different initial pressure ranging from 1 to 15 bars.

Image processing algorithms are used in order to detect and track agglomeration patterns from the moment they appear on the surface to their movement in the gas flow. The detections are post-processed in order to calculate metrics associated to the particles agglomeration, such as the fraction agglomerated, the residence time or the drag force. This enables a fine analysis of some governing parameters for agglomeration (AP granulometry, drag forces, surface retention), an important first step to establish a more general agglomeration model for aluminum particles. The study shows that the AP granulometry has a reduced influence on the inert particles agglomeration. The pressure however influences their agglomeration due to its influence on the gas flow velocity and thus the drag force applied on the particles.

References

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