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Corresponding author: Artur Elias de Morais Bertoldi
e-mail of corresponding author: *artur.elias.de.morais.bertoldi@ulb.be*
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Title

Combustion Instabilities Induced by Multi-Stepped Hybrid Rocket Fuel Grains

Authors

Artur Elias de Morais Bertoldi [1,2,], Christopher Glaser [3], Jouke Hijlkema[3], Jean-Yves Lestrade[3], Jérôme Anthoine[3] and Patrick Hendrick [2]*

** Corresponding author*
[1] Aero-Thermo-Mechanics Department, Université Libre de Bruxelles, 50 Avenue F. D. Roosevelt, 1050 Brussels, Belgium,
artur.elias.de.morais.bertoldi@ulb.be
patrick.hendrick@ulb.be

[2] Chemical Propulsion Laboratory, University of Brasilia, Brasilia, 72444-240, Brazil
artur.bertoldi@aerospace.unb.br

[3] ONERA/DMPE, Université de Toulouse, F-31410 Mauzac, France
christopher.glaser@onera.fr
jouke.hijlkema@onera.fr
jean-yves.lestrade@onera.fr
jerome.anthoine@onera.fr

Abstract

Positive characteristics like safety and lower cost, potentially, make Hybrid Rocket Engines (HREs) promising candidates in the *New Space* era. However, in order for HREs to be used widely in the space sector, its drawbacks need to be addressed and solved. Historically, HREs have been experiencing low solid fuel regression rates, O/F shifts and even low frequency combustion instabilities that are inherent to the HREs boundary layer combustion process [1]. Moreover, the geometry of the fuel grain has a considerable impact on the propulsive characteristics of the engine.
Previous research carried out by the authors using Forward Facing Steps (FFS) and Backward Facing Steps (BFS) in the solid fuel grain demonstrated increased regression rates compared to a cylindrical single port [2,3]. This behavior makes the utilization of (multi-) steps in HREs a promising option to tackle the problem of low regression rates. Nonetheless, it is important to assess the combustion instabilities induced by stepped geometries to anticipate (and solve) potential negative side effects. This paper addresses the preliminary experimental results for single and multi-step configurations and their combustion chamber pressure oscillations.
The phenomenon of combustion instabilities may occur in HREs independently of the scale of the motor and propellants used. Pressure oscillations in hybrid rockets are not likely to be as limiting compared to their liquid and solid counterparts. However, the instabilities might significantly affect the performance and payload comfort of the propulsive system, and therefore need to be characterized.
In this study, we analyze the interaction between the pressure oscillations in the combustion chamber and the other parameters of the HYCAT hybrid rocket motor at ONERA, using the innovative fuel grain geometries proposed by the

group [2,3]. The propellants used are Hydrogen Peroxide (H_2O_2) and High-Density Polyethylene (HDPE). The following four different fuel grain configurations are employed and investigated: a) cylindrical (baseline), b) FFS, c) BFS, and d) multi-steps. Using the computation tool *WaVer*, developed at the University of Brasília Chemical Propulsion Laboratory, and the methodology proposed by Bertoldi et al. [4] and Lee et al. [5], it was possible to post-process the pressure signal to characterize the dynamic influence of the fundamental frequency in the combustion chamber as a function of the pressure responses for each test.

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