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Author: Dr. Stefano Mungiguerra
Università degli Studi di Napoli “Federico II”, Italy, stefano.mungiguerra@unina.it

Mr. Sergio Cassese
University of Naples ”Federico II”, Italy, sergio.cassese@unina.it
Mr. Riccardo Guida
University of Naples ”Federico II”, Italy, riccardo.guida@euroavia.eu
Prof. Raffaele Savino
University of Naples ”Federico II”, Italy, raffaele.savino@unina.it

EXPERIMENTAL AND NUMERICAL ASSESSMENT OF REGRESSION RATE AND PROPULSIVE PERFORMANCE OF 10N-CLASS HYBRID ROCKETS FOR NANOSATELLITE MANEUVERING

Abstract

The hybrid rocket is a chemical propulsion engine in which fuel and oxidizer are separated in different physical states, generally the fuel stored in the combustion chamber in the form of a single- or multi-port solid grain and the oxidizer in a separate tank in liquid of gaseous phase. This category of chemical rockets is attracting research interest thanks to its numerous advantages with respect to traditional solid and liquid systems, which include re-ignition and throttling capabilities, combined with the possibility of employing environmentally sustainable propellants and, most importantly, intrinsic safety. The numerous advantages of hybrid rockets make them appealing in applications where simplicity, safety and compactness are strict design requirements, such as onboard small satellites (e.g. standard CubeSats). The thrust levels, relatively high with respect to electrical propulsion devices, enable a number of potential orbital maneuvers, including deorbiting, fast formation reconfiguration, orbit transfer, planetary landing.

Despite its potentialities, such propulsion technology still raises challenging tasks and, currently, is not yet adopted for actual space missions. Significant developments are still needed, even at laboratory-scale firing test level, for the characterization of propellants regression rates, propulsive performance, and subsystem design, especially in light of the objective of miniaturization, field still substantially unexplored in the relevant literature.

In the present work, a 10N-class hybrid rocket thruster, conceived as a ground breadboard of a nanosatellite propulsive unit, was tested in an instrumented test bench, measuring mass flow rates, pressures, temperatures, thrust, regression rates and characteristic velocities. The thruster is based on the catalytic decomposition of high-test peroxide, which allows for an autonomous ignition of the propellant mixture without external systems or secondary propellants. Different polymeric fuels, in the form of 40-mm long cylindrical port grains, were tested at different oxidizer mass flow rates and a ballistic reconstruction technique was used for the rebuilding of the instantaneous regression rate, providing a precious input for the design of in-space propulsion units. The experimental activities are complemented by Computational Fluid Dynamic (CFD) simulations of the rocket internal ballistics, based on non-premixed combustion models and dedicated fuel/gas interface conditions aimed at an estimation of the local fuel regression rate. Ongoing research activities foresee studies on the effect of different oxidizers on the performance and regression behavior, and the investigation on the effect of complex port shapes, based on the aid of additive layer manufacturing, for the optimization of rocket performance.