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Abstract
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Boosting Green Propellants: The Sustainable Armored Grain for Hybrid Rocket Propulsion

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Abstract

Hybrid Rocket Engines (HREs) could represent an affordable and effective propulsive alternative to the traditional solid rocket motors (SRMs) and liquid rocket engines (LREs) [1]. In fact, HREs seize the benefits of SRMs and LREs; namely, the reduced cost from the former and the operational flexibility (e.g., thrust modulation) from the latter [2]. The potential of this technology can be exploited by using liquefying fuels, such as paraffin-based formulations, which offer faster regression rate than conventional polymeric fuels. In this framework, the Space Propulsion Laboratory (SPLab) of Politecnico di Milano is studying paraffin-based formulations to create fuels with high ballistic performance and structural integrity [3]. In the last years, the combination of fast burning paraffin waxes and 3D printed reinforcements originates the armored grain [4,5]. So far, the results attested that armored grains exhibit faster regression rate and higher mechanical performance than traditional "non-armored" paraffin fuels. The armored grain pushed the hybrid propulsion technology towards faster and tougher fuels; is it possible to further improve this new class of fuel?

In recent times there has been a great concern about green propulsion technologies to contrast pollution and climate change. Traditionally, hybrid rockets are addressed to be "environmentally friendly" because of the low pollutant exhausts, if compared to SRMs. The choice of paraffin waxes instead of thermoplastic polymers goes towards HREs with reduced environmental impact. However, paraffins are generally derived from petrolatum. Is it possible to go more sustainable and greener using waxes in HRE?

This research targets at empowering the armored grain by developing a greener and more sustainable version. To do this, the two components of the armored grains (i.e, the paraffin matrix, and the polymer for the inner reinforcement) were modified. More specifically, bio-derived natural waxes were exploited: carnauba wax the and beeswax. Similarly, the 3D printer polymeric filament for the gyroid-like reinforcement has been substituted with commercial and in-house produced bio-polymeric filaments. The bio-waxes and the bio-polymers were characterized via thermal analyses, mechanical tests at compression, and firing tests in the lab-scale hybrid rocket motor. The most promising bio-waxes and 3D printed bio-polymeric reinforcements were combined to create a new eco-version of the armored grains. The latter was studied inspecting its mechanical and ballistic behavior to assess its feasibility in HREs and to pave the way to high-performance and more sustainable fuels.

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