NANO-SIZED ALUMINUM FOR SOLID FUEL REGRESSION RATE ENHANCEMENT

C. Paravan, A. Reina, A. Frosi, and L.T. De Luca
Politecnico di Milano, 34, via LaMasa, Milan, MI, I-20156, Italy

Solid Rocket Motors (SRMs) and Liquid Rocket Engines (LREs) are mature systems serving in several applications. The Hybrid Rocket Engines (HREs) offer attractive features that could improve the performance of both launch and in-space navigation systems [1]. HREs enable multiple firings, thrust modulation, and higher levels of safety with respect to solid propellants. The specific impulse of HREs is higher than the one of SRMs and close to the one of LREs. With respect to LREs, HREs are simpler in architecture and could result less expensive and more reliable. The main drawbacks of HREs are the low linear regression rates of the solid fuel grain, and the poor combustion efficiency.

This paper focuses on the regression rate enhancement of solid fuels for hybrid space propulsion. The investigated fuels are loaded with nano-sized Aluminum powders (nAl), an attractive candidate for performance improvement of hybrid systems thanks to its peculiar characteristics with respect to micron-sized Aluminum (μAl) and other conventional, coarser additives. In particular, tests performed by Differential Scanning Calorimetry-ThermoGravimetric Analysis (DSC-TGA) show a lower onset temperature of nAl oxidation [2]. The first oxidation phase of nAl is characterized by an intense heat release due to heterogeneous reactions between metal and oxidizer. This high reactivity can produce significant burning rate increases in solid propellants and fuels [2]. In spite of this, in the fuel manufacturing phase, the single nano-sized particles tend to form clusters; this behavior must be contrasted by dedicated procedures to disperse the additive down to the nano-scale.

In this work, different nAl powders were characterized and tested as additives in solid fuel formulations based on Hydroxyl-Terminated PolyButadiene (HTPB). Tested powders were produced by Electrical Explosion of Wires (EEW) or plasma condensation, and then passivated by dry air. The air passivated powders were compared to coated variants. Two different coatings were tested: the first one is based on Fluorel™ (a fluorohydrocarbon polymer) while the second one is based on HTPB. Powder coating aims at improving dispersion in the manufacturing phase and enhancing performance during combustion. Investigated powders were characterized in terms of physical parameters (mean particle size and size distribution, specific surface area, active metal content) and ignition temperature. The fuel formulations were tested in a 2D-radial burner. The corresponding data reduction was performed by a non-intrusive, optical, time-resolved technique. The relative ballistic grading of the tested formulations was done considering HTPB as baseline. The data reduction enabled evaluation of regression rate evolution during the combustion. In particular, relative grading of the tested formulations with respect to the baseline was performed for an initial oxidizer mass flux of ~400 $kg/(m^2s)$, with combustion chamber pressure of 1.0 and 1.6 MPa.

References

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