RHEOLOGICAL AND MECHANICAL BEHAVIOR OF COATED ALUMINUM LOADED NANO-COMPOSITES

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Metal nano-sized particles possess unique features with respect to coarser equivalent powders, and their use is in continuous growth in many industrial fields: cosmetics, pharmaceutics, energetic materials. In space propulsion application solid rocket propellants with total or partial substitution of micrometric Aluminum with nano-sized one show a significant improvement in performance: burning rate is increased while agglomeration phenomena are mitigated [1]. The addition of nanometric Aluminum to Hydroxyl-Terminated PolyButadine (HTPB), used as fuel in Hybrid Rocket Engines (HRE) could represent a good pathway to solve the low regression rate problem that hindered a wide exploitation of these systems. Although nanometric powders are characterized by very attractive bulk properties, their surface interactions can avoid a total development of their potential: Brownian motion, very effective on this scale, cause particles to collide and Van der Waals forces, relevant because of the high specific surface, promote cluster formation. Moreover surface interactions among nanoparticles cause an increase in viscosity of uncured propellant [2], leading to difficult manufacturing and casting.
A possible solution for both these problems consists in surface treatment of the nano-sized powders. In this work the effect of an HTPB coating on ALEX^{TM} is considered. In order to improve the quality of the coating, particles are treated with two different coupling agents, Catechol or Acetylacetone, and various percentage of HTPB, up to 5% are investigated. The effectiveness of the surface treatment is evaluated through mechanical and rheological analyses on both solid fuel for hybrid propulsion and solid propellant. Dynamic mechanical analyses are carried out on strands of cured materials: solid fuel is composed by HTPB loaded with 10% of nanosized Aluminum. HTPB/AP/Al solid propellants in which micrometric Aluminum is partially or totally substitute by nanosized powders are investigated as well. Coated powders obtained with various coupling agents and HTPB percentages are compared to standard Alex^{TM}. The same, but uncured, formulations, are tested using a Couette rheometer. Newtonian behavior is shown by compounds containing small fractions of solid particles, like fuels for hybrid systems. Increasing volumetric fraction a shear rate dependence appear. A complete characterization for heavily loaded formulations, increasing AP content is carried out in order to find a correlation between viscosity and volumetric content. Comparing uncured propellants loaded with ALEX^{TM} to formulations loaded with coated nanosized Aluminum it is possible to notice a decrease in viscosity for almost every shear rate.

References

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