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# Overview of Al-Based Nanoenergetic Ingredients for Solid Rocket Propulsion

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## ABSTRACT

The introduction of nano-sized energetic ingredients first occurred in Russia about 60 years ago and arose great expectations in the rocket propulsion community, thanks to the higher energy densities and faster energy release rates exhibited with respect to conventional ingredients. But, despite intense worldwide research programs, still today mostly laboratory level applications are reported and often for scientific purposes only. A number of practical reasons prevent the applications at industrial level: inert native coating of the energetic particles, nonuniform dispersion, aging, excessive viscosity of the slurry propellant, possible limitations in mechanical properties, more demanding safety issues, cost, and so on. This paper describes the main features in terms of performance of solid rocket propellants loaded with nanometals and intends to emphasize the unique properties or operating conditions made possible by the addition of the nano-sized energetic ingredients. Steady and unsteady combustion regimes are examined.

**Keywords:** nanoaluminum; solid rocket propellant; burning rate; combustion; propulsion; performance.

## BACKGROUND

In energetic applications, such as propellants, pyrotechnics, and explosives, Al is widely used because of its high combustion enthalpy, easy availability, low toxicity, and good stability. Aluminum, whether powders or flakes, is used to increase the energy and raise the flame temperature in rocket propellants (a direct but awkward way to increase specific impulses); it is also added to explosives to enhance air blast, raise reaction temperatures, create incendiary effects, and increase bubble energies in underwater weapons. In rocket propulsion, combustion processes of conventional micron-sized Al (μAl) powders proceed relatively far from the propellant surface and do not significantly contribute to the propellant burning rate. On the contrary, ultrafine energetic particles, especially nano-sized ones, are objects characterized by very small size and subsequently very high specific surface area. Thus, they appear very attractive because of their different chemical and physical properties, compared to the corresponding bulk or micron-sized materials. Especially nano-sized Al (nAl) is broadly exploited to improve performance incrementing the burning rate and combustion efficiency of energetic systems, leading to shorter ignition delays and shorter agglomerate burning times with respect to energetic systems containing μAl. As a matter of fact, the rapid acceleration of research in the area of metal-based reactive nanomaterials can readily be traced back to the development in nAl manufacturing.