# Hypergolic Ignition Behavior of Kerosene Gel Containing Aluminum Nanoparticles with Hydrogen Peroxide Using a Novel Drop Test Method

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## Abstracts

Hypergolic gels with metallic additives provide reliable ignition and enhanced safety, making them well-suited for space and tactical propulsion. This study investigates the hypergolic ignition behavior of aluminum-loaded kerosene gel with 95% hydrogen peroxide ($H_2O_2$) using a novel drop test platform designed to resolve early-stage ignition dynamics and the self-sustainability of the reaction after ignition.

In this setup, 95% $H_2O_2$ droplets impinge upon a 300 µm-thick film of kerosene gel, and the ignition process is recorded using high-speed cinematography. The gels are catalyzed using 5 wt.% sodium borohydride ($NaBH_4$) to ensure hypergolicity. This drop-on-film configuration offers a well-defined, reproducible, and quantitatively controllable impact condition, while improving experimental safety by minimizing the quantities of reactive materials in each test. The baseline gel is composed of kerosene thickened with Thixatrol, while the energetic formulations include aluminum nanoparticles at varying loadings from 5 to 30 wt.%. Two types of aluminum particles were evaluated: commercial 50 nm nanoparticles with native oxide layers, and in-house synthesized particles coated with triphenylphosphine $PPh_3$.

The base gel demonstrates initial boiling, droplet breakup, satellite splashing, and a brief ignition event that quickly quenches. In contrast, gels containing 5 wt.% commercial aluminum nanoparticles show reduced splashing, intensified localized reactions, and bright sparks likely originating from reactive aluminum ejections. These effects culminate in self-sustained flame propagation along the gel surface, a behavior absent in the unmodified gel. Despite the dramatic change in reaction outcomes, the ignition delay, defined as the time between droplet impact and the formation of a bubbling blob, remains unchanged with 5 wt.% particle loading. The developed testing approach not only reveals detailed early-stage ignition phenomena but also serves as a tool to assess whether initial ignition events can evolve into sustained reaction fronts. Ongoing experiments continue to explore the influence of particle loading and aluminum nanoparticle protective layer on ignition characteristics.

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