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DEVELOPMENT AND PERFORMANCE TESTING OF A "GREEN" HYDROXYLAMMONIUM NITRATE-BASED MONOPROPELLANT IN A LAB-SCALE THRUSTER

Abstract

Recent advancements in safety and emissions regulations have driven the development of non-toxic propellants for military and commercial low-thrust applications, such as reaction control systems (RCS) and orbital manoeuvring engines in satellites. Traditionally, these systems rely on hypergolic hydrazine-based fuels and nitric acid derivatives, which generate toxic vapours and require specialized handling. To address these challenges, monopropellants such as ammonium dinitramide (ADN; NHN(NO)) and hydroxylammonium nitrate (HAN; NHOHNO) have been developed, offering significantly reduced toxicity and environmental impact while maintaining competitive performance.

In its solid state, HAN is a highly energetic salt containing both oxidizing and reducing components, rendering the anhydrous form unstable and potentially explosive. To mitigate these risks, HAN is commonly used in concentrated solutions and often blended with fuels like methanol to improve performance. A particularly promising formulation is JAXA's SHP163, a ternary HAN-based monopropellant that remains insensitive, requiring a heated catalyst for ignition. Offering a vacuum Isp of 276 s, a density Isp of 396 sg/cm, and a freezing point below -30C, SHP163 is regarded as one of the most energetic yet safe liquid monopropellants currently available. Gelling additives can further improve its performance, which enhances long-term stability, increases throttling capability, and improves operational safety.

This study has successfully evaluated the performance of SHP163 in thruster firing tests using catalysts of varying grain sizes and bed lengths. A specialized decomposition chamber enabled the testing of two catalyst sizes: a fine mesh (20-30) on the injector side to accelerate propellant decomposition, reducing ignition and response time and pressure fluctuations, and a coarse mesh (14-18) after to ensure complete combustion and system stability. Optimization configurations have been identified by adjusting the length of these catalyst sections. Additionally, the modular thruster design allows for variations in chamber

length to assess its impact on overall performance. Comparative tests utilizing platinum- and iridium-coated alumina granules further refined catalyst selection. The initial catalyst bed temperature was also investigated for a range of 200 - 300C to optimize the starting conditions for each catalyst bed length configuration.

The findings from these tests directly inform the final design of a flight-ready thruster optimized for either gelled or liquid SHP163. Given the propellant's proven performance, safety, and adaptability, this research represents a significant step toward commercialising HAN-based propulsion systems, offering a viable alternative to conventional toxic propellants.