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INVESTIGATION OF NOVEL REGENERATIVELY COOLED CERAMIC THRUSTER FOR WATER ELECTROLYSIS PROPULSION SYSTEMS

Abstract

The Institute of Space Systems (IRS) at the University of Stuttgart is developing a green water electrolysis propulsion system for small satellites. The primary objective is to replace the conventional and highly hazardous hydrazine propellant. In addition, using water – which is split through electrolysis in orbit – not only increases fuel efficiency of the chemical thruster but also drastically reduces handling complexity and corresponding costs, making it particularly attractive to smaller institutions and entities with smaller budgets. This water propulsion system is one of the technology demonstrations on the institute's ROMEO mission, a small satellite scheduled for launch in 2026. This paper focuses on the presentation and testing of the latest iteration of the novel ceramic 1 N thruster with integrated regenerative cooling.

The previous version of the thruster was constructed from 3D-printed SiAlON ceramic and featured a tri-coaxial injector. Cooling was achieved by applying an H_2 cooling film on the inner combustion chamber wall, and ignition was initiated by a short flow of hydrogen and oxygen through a catalyst chamber. In the new iteration, a regenerative cooling system is implemented to potentially increase thruster efficiency and allow for further modifications like switching to a swirl-injector design. For one, the reduced thermal shock enables the investigation of doped mullite and alumina as alternative ceramic materials with the same manufacturing process. An alternative ignition concept utilizing fuel-rich continuous pre-combustion in the catalyst chamber is also tested. This approach may increase overall efficiency by eliminating cold gas ejection during ignition and reducing catalyst degradation through the prevention of thermal shock and high temperatures. During testing, the fuel ratio will be adjusted and analysed, as will the mass flow proportion of the hydrogen cooling film to the central injector. These adjustments aim to optimize efficiency for specific burn durations without exceeding operational temperatures. Additionally, variations in injector and combustion chamber designs are examined and compared. Furthermore, the entire injector design has been reworked for both cooling concepts to improve printability and intermixture of the gases. Since combustion simulations indicate that various minor adaptations to the current prototype can significantly enhance performance, their influences will be characterized experimentally. Also, first blow-down test results will be presented to determine the operational range of the thruster and re-evaluate the chosen thruster size.