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# EXPERIMENTAL STUDY OF WATER AND ALUMINUM COMBUSTION AIMING FOR A NOVEL PULSED-CHEMICAL MICROPROPULSION SYSTEM

**Abstract**

Water is an attractive propellant for micropropulsion systems due to its high mass density under standard conditions, high safety, and high availability even on the Moon and on Mars. In 2023, a 6U CubeSat EQUULEUS, demonstrated orbital transfer with a water resistojet thruster, AQUARIUS. This success has the potential to contribute to deep space exploration by the private sector. Chemical micropropulsion also has the potential to enhance the capabilities of nano-small sized spacecraft. It is essential for short-time maneuvers which allow the execution of challenging missions. However, classical chemical propulsion systems have various disadvantages in this context. These include the use of dangerous propellants, e. g. hydrazine, and of high-pressure systems. Both increase development costs. In this situation, we propose a chemical micropropulsion system that uses water vapor as the oxidizer and powdered aluminum as the fuel. Powdered aluminum does not affect the advantageous properties of water. It is also inexpensive, non-toxic, easy to handle, widely available, and offers gravimetric and volumetric energy densities that are comparable to hydrazine. Our micropropulsion system adopted a pulsed-firing operation to eliminate the need for a highly pressurized system. This minimizes costs that are associated with safety measures. The concept was tested on breadboard models, which were developed from May 2023 onwards to study powder supply strategies and the combustion process. The paper reports on the status of this project. For the powder supply system, a pinch-type valve was built to control powder injection. With a target 0.1U-class combustion chamber, the following values were measured: injected powder mass per shot, $m_{\mathrm{Al}}$, mass flow rate, $\dot{m}_{\mathrm{Al}}$, and the ratio of powder and gas mass flow rates, $\phi$. Stable pulsed supply was demonstrated with micron-sized aluminum powder for 1 g/s $\leq m_{\mathrm{Al}} \leq$ 10 g/s, and $300 \leq \phi \leq 400$. The injected powder mass was 0.5 g/shot $\leq m_{\mathrm{Al}} \leq$ 1 g/shot, and the largest standard deviation was 17.9%. These values can be controlled with the carrier gas pressure and mass flow rate. Combustion pressures, combustion temperatures, and reacted aluminum fractions were also measured to characterize the combustion process. The gathered data was then used to estimate performance levels. Time averaged thrust was determined to be in the 100 mN-class and specific impulse in the 100 s-class. That means that the proposed thruster offers propulsive performance that is comparable to other chemical propulsion without the need for special safety measures or high-pressure systems.