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Title
Vacuum Test Campaign of a Hydrogen Peroxide Propulsion System for CubeSats

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Abstract
In recent years, CubeSats have become a significant player in the space industry thanks to their compact size, simplicity, and low cost. Their spectrum of applications is incredibly wide and versatile ranging from scientific technology demonstration, and communication missions to earth observation. In this context, Green Propellants, less toxic than classic rocket chemicals, are the perfect choice to be implemented and tested, allowing small satellites to compete against more popular solutions such as electric propulsion. Although the requirements for these small satellites are stringent, in terms of mass, envelope, and power consumption, the University of Pisa, winning the call from ESA with the CHIPS project (CubeSat HTP Innovative Propulsion System), has been able to design, manufacture and test an affordable Hydrogen Peroxide monopropellant propulsion system. The advantage of chemical propulsion systems compared to electric ones can be expressed in their high-thrust-to-weight ratio allowing the system to perform impulsive maneuvers and attitude control. In the CHIPS framework, two different test campaigns took place, the first one in the atmosphere and the second in vacuum conditions having the intent to demonstrate that Hydrogen Peroxide can be a good substitute, in terms of performance, for the more toxic hydrazine. This paper presents the results obtained from the first hot-firing test campaign conducted in vacuum conditions in the electric propulsion facility of ESTEC (European Space Research and Technology Center) in the Netherlands. The objective of this study was to test the entire propulsion system in conditions similar to the operative ones. For this reason, modifications performed on the vacuum chamber allowed it to accommodate a chemical engine, and a coating covering the chamber's walls prevented any damage caused by eventual droppings of Hydrogen Peroxide. Testing in vacuum made possible the computation of the specific impulse of the system and the estimation of the operating temperature of the components. The test matrix followed during the test campaign did not change from the atmospheric case, and the system underwent several firings, from 80 s continuative to pulses of 25 ms of firing valve opening time. The setup used during this test campaign was similar to the one adopted in atmospheric conditions: 98% wt. Hydrogen Peroxide as the propellant, and alpha Platinum Alumina pellets as the catalyst. The only difference in setup with respect to the previous atmospheric test campaign was the configuration of the catalytic bed. As in the atmospheric case, the results showed that the propulsion system performed according to expectations and that it can satisfy most of the requirements both in continuous and pulse mode, obtaining a thrust equal to 0.5 N with a nominal specific impulse of 160 s. The temperature of the components remained below the operative limits for the entire test duration, even without air convection. This first vacuum campaign gave a deeper insight into the true performance of the propulsion system and suggested the path to follow for further improvements.

References
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