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MODELING, SIMULATION AND TESTING OF AN INNOVATIVE ENGINEERING MODEL WATER-BASED PROPULSION UNIT FOR CUBESATS

Abstract

The Cubesat industry is steadily growing year by year, demanding cheaper, sustainable, and high-performance propulsion systems. To meet such demand, we have started the development of a new water-based propulsion unit, called "WaterCube", to serve as primary propulsion for Cubesats and attitude control for Smallsats.
The propulsion unit is made of the functional components described hereinafter, and fed with demineralized water.

1. Main Water Tank (MWT): this is the main storage tank for the propellant;
2. Vaporization Cell (VC): it is placed downstream the MWT and isolated from it with a valve. It is a proprietary heat exchanger used to vaporize the water coming from the MWT.
3. Thruster (THR): it is placed downstream the VC and isolated from it with a valve. It is heated with a resistive coil to further increase the steam temperature before its expansion in a De Laval nozzle.
4. PowerControl Board: it is the board used to control the unit by means of pressure sensors, temperature sensors, heaters and valves.

We developed a Matlab-based model to simulate the 1-D behaviour of the integrated propulsion unit engineering model, in a thermal-vacuum chamber, in order to correlate and validate the as-designed unit with the as-built and tested one, highlighting the unique contributions of the proprietary VC technology. By careful selection of valves Kv, heaters power, VC design and fluidic lines pressure drops, we managed to obtain a steady water flow, whereby the unit can be operated without the need to load and recharge the VC, but rather by simply keeping a steady vaporization flow through the VC and nozzle by regulating the aforementioned parameters. The most relevant design parameters investigated in the modeling and simulation phases are: heaters power consumption, massflow rate, nozzle inlet pressure, nozzle inlet temperature, MWT VC pressure and temperature, specific impulse, thrust in vacuum and water vapour fraction at nozzle outlet.
The experimental parameters acquired by the data acquisition system are total system power consumption, nozzle inlet pressure, nozzle inlet temperature, thrust in vacuum, MWT and VC pressure and temperature. Experimental data from the thermal-vacuum chamber test validate the simulation results, confirming the system's proper operation and the absence of water re-condensation at the nozzle outlet. These promising results pave the way for advancing the detailed design phase of the flight model, slated for launch in Q3 2025, having reduced the uncertainties on system operations that always come with new developments.