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SPACE PROPULSION SYMPOSIUM (C4)
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CLOSED-LOOP THRUST CONTROL FOR MICROPROPULSION SYSTEMS

Abstract

The growing needs of nano- and pico-satellite missions require several enhancements in micro-propulsion capabilities to enable the satellites to perform an increasing variety of orbital maneuvers. Among them, the possibility to accurately control the thrust would open up new scenarios for nano- and pico-satellites applicability to include, for example, missions such as space debris removal and orbit transfer. This paper presents the design and the implementation of a closed-loop control system for thrust magnitude regulation in micro-resistojets. This is achieved by controlling the propellant mass flow in the micro-valve of the feeding system which is designed to make extensive use of off-the-shelf components. The Vaporizing Liquid Micro-resistojet (VLM) is one of the micro-thrusters under development at TU Delft and, for this reason, it is selected for performing the tests. The outcome of this work is meant to give insights into the design and performance level of future technologies for thrust magnitude control, which will be designed and manufactured at TU Delft. In order to develop appropriate controllers, a non-linear state-space model of the micro-valve system is developed analytically. The model includes different domains, such as electromagnetic, fluid and mechanical, in order to bring together the complex dynamic behavior of the actuator. The performance of the analytical model is compared to a more sophisticated multi-domain analysis done with finite element method (FEM) and computational fluid dynamics (CFD). Two controllers, namely PID (proportional-integral-derivative) and SMC (sliding mode control), are designed and tested using the models developed. The control algorithm is also adapted based on the different type of micro-valves adopted in the design. In particular, proportional micro-valves require a voltage level as input, whereas ON/OFF devices are controlled with PWM (pulse width modulation) by tuning the operating duty cycle. Finally, the closed-loop control system is implemented in the preliminary hardware design of the micropropulsion system. The experimental set-up comprises the propellant tank, the micro-valve, the micro-thruster, the feeding channel, pressure and temperature sensors and the processing microcontroller. The tests are focused on the performance of the controller, and the fine tuning of its parameters, and also in the validation of the design approach.