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ACTIVELY PULSED DUAL HEATING IN VAPORIZING LIQUID MICROTHRUSTERS: AN INTEGRATED ANALYSIS COMBINING NUMERICAL SIMULATIONS AND EXPERIMENTS.

Abstract

The development of MEMS technology in recent years has enabled the interest in micropropulsion systems for small satellites (total mass < 10 kg) used for Earth observation. The use of these satellites needs a more precise attitude control system to ensure high-pointing precision. One of the more attractive concepts is the vaporizing liquid microthruster (VLMs) due to its simplicity and the important advantage of using liquid like a propellant allowing lighter and smaller propellant tanks. VLMs can provide nominal thrust forces ranging between 0.1 and 10 mN with specific impulses (Isp) above 100 s for water. However, their current technology readiness level is still below 5 due to the occurrence of flow boiling instabilities arising when transforming the liquid into vapor. Such flow boiling instabilities need to be properly controlled as they can degrade the thermal/propulsive performance and be detrimental to device longevity at the same time. With the collaboration of the Institute for Microelectronics and Microsystems IMM-CNR (Italy) and the support of the KU Leuven (Belgium), the Aerospace Propulsion group at the University of Salento has developed a novel water-fed MEMS VLM concept equipped with a dual heating system coupled with microsensing capability via embedded thermistors/vapor quality capacitive sensors. Such a design is based on previous studies that highlighted severe limitations when working with a single heating system and geometry. The new proposed configuration involves two distinct chambers equipped with a dedicated heating system. The design logic is splitting the heating process into two steps to decouple as much as possible the boiling and heating processes, thus ensuring a more effective and controlled vaporization sequence. In the present work, a numerical performance analysis of the VLM undergoing actively controlled dual pulsed heating is provided, delving into the thermal aspects of the design. To this purpose, an in-house quasi-1D VLM model is used. Results prove the importance of implementing a dual heating strategy to minimize thermal stresses and maximize the device's lifetime. The numerical assessment is complemented by an experimental characterization of the thermal and propulsive performance of a real device. This approach gives us a strong and reliable testing setup, ensuring accurate data collection for understanding how the device performs. The most relevant insights are outlined and discussed.