IAF SPACE PROPULSION SYMPOSIUM (C4)
Joint Session between IAA and IAF for Small Satellite Propulsion Systems (8-B4.5A)

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A COMPACT AND HIGH THRUST-TO-POWER MICROPROPULSION SYSTEM USING ULTRASONIC VIBRATING MESH TECHNOLOGY FOR POCKETQUBE APPLICATIONS

Abstract

In response to the increasing cost of cubesat missions, PocketQube (1p = 5 x 5 x 5 cm, 250 g) was introduced in 2009 as an alternative and smaller version educational tool to train university students or engineers, as well as for the amateur radio satellite builder communities to initiate their satellite project. It is challenging to integrate a propulsion system into a PocketQube of inherently small spatial volume and low system mass, without compromising the optimal functioning of other subsystems. To address this constraint, we are investigating a conceptually simple and, thus highly compact micropropulsion system based on vibrating mesh technology. Vibrating mesh is a thin stainless-steel plate with laser-drilled micro-apertures, and attached to a piezoelectric ring, which vibrates at ultrasonic frequency upon connecting to an external driving circuit. The rapid vibration of the mesh creates a micro-pumping action that ejects a stream of ultra-fine droplets at high speed. A highly compact proof-of-concept prototype (38 x 37 x 25 mm) has been designed and developed using commercial-of-the-shelf (COTS) components. The main structure was additively manufactured for rapid prototyping and flexible integration of components into a small footprint. The total dry mass of the system (including the driving circuit) is only 26 g. Propylene Carbonate (PPC), a safe and widely available industrial solvent was selected as working fluid as it has low freezing point (-48.8 degC) and high boiling point (242 degC). Pressurized tank is not needed as the PPC can be stored in a porous foam, which allows the transport of liquid to the vibrating mesh via capillary suction. Such unique features facilitate the fluid handling and storage of working fluid. The thrust produced by our first prototype is 103.8 μN, measured using a sub-micronewton precision torsional thrust stand. The driving circuit is operating at 110 kHz and consuming 0.72 W (12V and 0.06A) of electrical power, giving a thrust-to-power ratio of 146.20 μN/W. The mass flow rate was measured at 0.94 mg/s, yielding a specific impulse of 14.1 s. Our proposed micropropulsion concept can be implemented in a PocketQube, as the associated prototype is well within its design envelop in terms of spatial volume, mass, and electrical power.