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THRUST AUGMENTATION AND VECTORING CONTROL IN A PLANAR MICRONOZZLE OF MICRO-RESISTOJETS BY MEANS OF SECONDARY INJECTION

Abstract

In the space sector, the advancements in micro-fabrication technology has driven the research effort towards the development of nanosatellites (total mass below 10 kg). They usually require thrust forces below few millinewtons for attitude control and pointing system. In this context, Micro-Electric-Mechanical Systems (MEMS) based micro-resistojets demonstrate to be a promising solution thanks to the functional simplicity which well meets the MEMS manufacturing technology. When operating with liquid propellant, they are known as vaporizing liquid microthrusters (VLM): they can store larger amount of propellant into lighter and smaller propellant tanks. Instead, in a gaseous fed configuration, they are called cold gas (CG) microthurster: they can ensure more stable performance since tehey are not affected by two-phase flow instabilities. However, high-pressurized heavy tanks are required for the propellant storage.

The microthruster performance is significantly affected by the viscous losses during the supersonic expansion into the micronozzle, due to the boundary layer growth along the depth-wise direction. This can lead to the flow blockage and viscous heating of the expanding flow inside the micronozzle. Furthermore, thrust vectorization is usually obtained by using microthruster array configurations. However, an alternative and more compact solution is represented by the introduction of active flow control (AFC) systems for exhaust jet deflection.

In the context drawn above, the use of the secondary injection represents an interesting and effective flow control strategy for both viscous losses mitigation and thrust vectoring application. In fact, additional microchannels can be properly designed in order to equip the device with a fluidic AFC. This would also results in reduction of mass and system complexity in comparison to the mechanical AFC, thanks to the replacement of the heavy and robust actuators, with only the fast-opening valves.

The present paper examines active flow control by steady micro-jet blowing applied to a literature planar micronozzle. The secondary injection flow control (SIFC) can operate in dual-mode operation: i) symmetric injection aiming to thrust augmentation by means of viscous losses mitigation; ii) asymmetric injection aiming to thrust vectoring control. Numerical simulations have been performed using OpenFOAM toolbox. A sensitivity analysis of the micro-jet intensity, position and operative configuration (i.e. single jet and multiple jets) have been carried out; hence, the impact of the fluidic actuation on the overall micronozzle performances have been assessed. Two different propellants have been considered, namely water vapor and gas nitrogen, which relate to their use in VLMs and CG microthrusters, respectively.