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PERFORMANCE IMPROVEMENT OF MEMS MICRO-THRUSTERS THROUGH NOVEL DOUBLE DEPTH AEROSPIKE DESIGN

Abstract

The introduction of the CubeSat standard in 1999 resulted in an explosive growth of nano- and pico-satellite missions. Micro-propulsion is universally regarded as a key technology, enabling these satellites to take the next step and become compelling alternatives for complex missions. In this context, Delft University of Technology is developing various micro-propulsion systems for CubeSat and PocketQube missions.

A major concern in the development of such micro-propulsion systems is the significantly increased viscous losses encountered in the nozzle. The viscous losses, associated with the low throat Reynolds numbers, limit the usability of micro-propulsion systems. A promising solution is the use of linear aerospike nozzles, which mitigates a portion of the viscous losses by removing the walls normal to the nozzle profile, thus reducing the flow-wall interactions.

This paper presents the results of the design, numerical study, and fabrication of a novel double depth aerospike micro-nozzle. This micro-nozzle uses different depths before and after the nozzle throat, aiming to reduce over-edge expansion losses encountered in single depth aerospike nozzles. The steady state micro-nozzle performance is evaluated through three dimensional numerical simulations, using a continuum model, with nitrogen gas as the working fluid. The numerical simulations are performed over a range of spike depths between 200 and 1000 μm, and for the throat Reynolds numbers in the range of 191 to 2861. Additionally, linear micro-nozzles with varying divergence half angles ($\theta = 15° - 45°$), and single depth linear aerospikes truncated at 20%, 40% and 60% are investigated. Evaluation of the results shows that the double depth aerospike micro-nozzle outperforms both the linear and single depth aerospike nozzles across the entire range of investigated Reynolds numbers. That is, with performance improvements between 23% and 39% compared to the best performing linear nozzle. Also, indications will be given on the manufacturability of this novel micro-nozzle geometry using microelectromechanical systems (MEMS) fabrication techniques. Thus, with the application of the double depth aerospike nozzle geometry, doors are opened for new complex nano- and pico-satellite missions.