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MULTIPHASE FLOW MODELING IN MICRO-THRUSTER USING LATTICE BOLTZMANN METHOD

Abstract

Cubesats and smaller spacecraft standards have become an increasingly popular choice due to their low cost, flexibility and relative short development time. Various propulsion unit concepts are being developed to extend their mission capabilities and lifetime. One such concept is the Vaporizing Liquid Micro-thruster (VLM), a type of MEMS resistojet in which a propellant, such as water, is vaporized and accelerated through a nozzle to produce thrust. Incomplete propellant vaporization results in a multiphase flow which has a negative impact on thruster performance. Conventional numerical models used to analyze the multiphase flow fail to encompass the complex phenomena occurring in the vaporization chamber. They require complicated phase tracking algorithms and artificial nucleation sites, and still would neglect certain phenomena such as explosive boiling.

This study aims to characterize and quantify the multiphase flow entering the nozzle by simulating the phase change inside the vaporization chamber, using the mesoscopic lattice Boltzmann method (LBM). LBM is a novel computational fluid dynamics method, based on kinetic theory, that has only recently gained enough maturity to apply it to engineering problems. The LBM provides a unique perspective due to its bottom-up approach for solving complex multi-physics fluid flow problems. The phase change is modeled via the pseudopotential multiphase method in combination with the Peng-Robinson equation of state. This means that phase change, separation and flow is emergent from the method and thus does not require tracking of the phase interface, nor are numerical nucleation sites needed to initiate boiling. The LBM is well suited for complex geometry and thus can simulate most vaporization chambers, including porous ones.

In this contribution, the analysis of the multiphase flow is performed on transient simulations to allow pressure to vary in time, thus accounting for pressure sensitive phenomena such as explosive boiling. The findings presented include the nozzle entrance vapor quality, number of droplets and distribution. Analysis of simplified vaporization chambers are used to perform a sensitivity study for design parameters. The model is validated by comparing the multiphase performance impact of existing thrusters against the predicted performance impact with the simulated multiphase flow. These results will help make informed design choices for future vaporization chambers, thus making the most effective usage of the limited capabilities of small spacecraft.