

Design & Performance Analysis of a Bio-Inspired Micro-Thrust Nozzle for Enhanced Cold Air Thrust Applications

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Abstract

The demand for compact, efficient, and sustainable propulsion systems for CubeSats and small satellites has accelerated research into alternative cold-gas thruster technologies. Conventional convergent-divergent (C-D) nozzles, although simple and reliable, often suffer from plume divergence and reduced thrust efficiency when scaled down to miniature thruster sizes. This project introduces a bio-inspired nozzle design, modelled on the breathing mechanisms of whale and dolphin blowholes, which naturally optimize fluid flow for efficient exhalation. By integrating a controlled lip curvature and variable contraction profile, the design aims to achieve enhanced plume collimation, reduced turbulence, and improved axial thrust efficiency compared to standard C-D geometries. The nozzle is intended for 3D printing using lightweight materials, ensuring low-cost fabrication and rapid prototyping. Computational Fluid Dynamics (CFD) simulations will be employed to validate the flow characteristics and performance improvements of the blowhole-inspired design against conventional nozzles. Initial assessments suggest that the proposed geometry can offer a more stable and directional plume, critical for attitude control in small spacecraft.

Keywords

Bio-inspired nozzle, Cold-gas thruster, Computational Fluid Dynamics (CFD), CubeSats.