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PROPELLANT LINE DIMENSIONING FOR 'GREEN' CUBESAT MONO-PROPELLANT PROPULSION SYSTEMS

Abstract

CubeSats are historically recognized as popular platforms for applications such as Earth imaging or demonstration of new technologies, typically in low Earth orbits with short mission duration. However, these small satellite platforms are recently starting to be proposed also for more ambitious missions, including interplanetary ones such as Moon, Mars or asteroid exploration. These missions are typically characterized by longer duration and often require an active propulsion system, for orbital transfer and/or station keeping maneuvers. Although commercial-off-the-shelf propulsion options exist, some missions may require a partially or even completely customized solution. When customization of the propulsion system is required, proper dimensioning and selection of components such as valves, fittings and feed lines is imperative to keep component mass to a minimum while keeping the flow velocity low to minimize pressure drop and fluid hammer effects. Excessive pressure drop over these components may result in requiring higher upstream pressure and, ultimately, higher tank mass. The maximum acceptable pressure drop is often included among the propulsion sub-system requirements, already in the very early design stage. However, not many methods have been proposed so far for sufficiently accurate theoretical estimation of this pressure drop, prior to any manufacturing and testing of engineering models. The pressure drop requirement imposed in early project phases therefore typically relies on historical data which may not be fully applicable, rather than mathematical approximations based on design considerations. This paper proposes a methodology to optimize the design of tanks and propellant lines through mass minimization. To show its effectiveness, the methodology is applied to a specific study case: a custom-designed propulsion system for the LUMIO mission, a 12U Lunar CubeSat using micro- thrusters based on "green", non-toxic propellants. Given the typically laminar flow in the feeding lines of these micro-propulsion systems, the Hagen and Poiseuille relation is used to estimate the friction factor; where the flow becomes turbulent, the Blasius correlation is also considered. An optimization process is applied to the given design space, to find a minimum for the system dry mass (target function), using the pipe diameter and length as design variables, for different possible propellants. Application of this methodology to the study case results in significant reductions of the estimated tank and feeding line mass, when compared to existing systems of similar characteristics. The method therefore proves to be a valuable early-design tool for CubeSat propulsion engineers, allowing for reliable mass and volume estimates.