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PERFORMANCE ANALYSIS OF DIFFERENT AIR INTAKES FOR ABEP IN VLEO AND EVALUATION OF SCALE EFFECTS

Abstract

In recent decades, numerous studies have been conducted on Air-Breathing Electric Propulsion (ABEP) for satellites operating in the Very Low Earth Orbit (V-LEO). The satellite's operating regime is found to be in a rarefied environment, so the Direct Simulation Monte Carlo is necessary to conduct these studies. By utilizing air intakes capable of capturing numerous particles, which are then ionized and transported to an electric thruster, it becomes feasible to attain a thrust able to counteract all or some of the aerodynamic drag, that commonly affects operational altitudes, ranging from 150 km to 350 km. This substantially extends the satellite's operational lifetime.

The limited availability of data to validate scaling laws and modeling efforts is due to the difficulty of recreating the VLEO environment in the laboratory. The evaluation of intakes in the V-LEO environment is based on their compression ratio and capture efficiency, which are determined by the intake geometry. The intake performance is affected by the interaction between external particles and the body wall, making it important to assess different reflection patterns (specular and diffuse reflection).

The study evaluated the performance of intakes with different geometries, wall reflection models of particles in the atmospheric environment and different wall temperature using DS2V software. The obtained compression ratio and capture efficiency results are consistent with the literature. In addition, scaled models of the intakes, with dimensions compatible with CubeSat, were also considered to envision their integration and the use of an ABEP system for this type of satellite. A trend of velocity, number density and density along the axis of the intake coincident with the 1:1 scale is obtained. So, the particle flow rate supplied to an electric thruster decreases proportionally to the outlet area of the intake. The study simulated various asymptotic flow conditions involving multiple species, including Nitrogen, Oxygen, and Atomic Oxygen, based on the NRLMSISE-00 and MSISE-90 atmosphere models. The results indicated a particle flow rate of tenths of milligrams per second.

The Italian Aerospace Research Center (CIRA) has recently focused on designing and testing Hall-effect thrusters, with focus on both conventional propellants and air-breathing systems. Within this framework, the present study could also be a baseline for designing ground demonstration systems for ABEP technologies.