Paper ID: 83491
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (2) (6)

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A MIXED VERIFICATION APPROACH FOR AIR-BREATHING ELECTRIC PROPULSION

Abstract

Air-breathing electric propulsion combines an air intake with an electric thruster to collect and accelerate the atmospheric particles in front of the spacecraft. Collecting the propellant from the atmosphere could enable long-duration space missions at very low altitudes, but the complexities of reproducing on-ground an environment representative of VLEO spaceflight hindered the development and the technological maturation of the concept [1]. In the framework of the BREATHE ERC project [2] and the ARIA FISA project, two different but synergic strategies for the characterization of air-breathing propulsion are being developed, merging experiments with modelling and simulations. In this work, we present the design of the BREATHE facility and the parallel development of a numerical suite to simulate the main physical processes of atmospheric neutral and plasma flows. In parallel, a second testing approach based on a rarefied atmospheric flow source and DSMC simulations is being pursued in a joint effort by the Sant'Anna School of Advanced Studies and the University of Pisa for the verification of air-breathing electric thrusters.

When a thruster is pipe-fed via a mass flow regulator, this typically implies a linear relation between the injected mass flow and the gas pressure, resulting in conditions not representative of thruster operation in air-breathing mode. The BREATHE facility comprises a main chamber (M) and an auxiliary chamber (A), which feature dedicated pumping systems. The equipment under test (i.e., the open-inlet air-breathing thruster) will be placed at the interface between the two chambers. By independently regulating the injected mass flow rate and the pressure difference between the two chambers, it will be possible to fine tune the flow properties (in terms of particle flux and pressure) inside the thruster control volume, and thus achieve a good level of representativeness of thruster operation in air-breathing mode. In parallel, the development of a flow source capable of reproducing rarefied fluxes of neutral particles, to be performed in the framework of the ARIA project, will allow for characterizing the intake collection and the effectiveness of integrated thruster-intake configurations.

In combination with state-of-the-art flow modelling techniques and data analysis implemented in the BREATHE Virtual Lab, the mixed physical-virtual laboratory environment will provide an effective platform for the development of air-breathing propulsion systems, contributing to the realization of next-generation air-breathing satellites.

[1] Andreussi T., Ferrato E., Giannetti V. (2022), Journal of Electric Propulsion 1 (31)
[2] ERC GA 101088694 "BREATHE", https://doi.org/10.3030/101088694