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EXPERIMENTAL TESTING AND NUMERICAL SIMULATION VALIDATION OF AN AIR INTAKE FOR AIR-BREATHING ELECTRIC PROPULSION (ABEP) SYSTEMS

Abstract

This paper presents (i) recent development in air-intake design for ABEP systems conducted by Kreios Space, (ii) including experimental testing to compute the efficiency of a state-of-the-art geometry [1,2], (iii) numerical verification of the experimental results with a Direct Simulation Monte Carlo (DSMC) code, and (iv) validation of the simulation setup through comparison with published air-intake cases [3].

The experimental setup has been implemented at the Drag-On [4,5] facility in the Von Karman Institute for fluid dynamics, where a controlled environment is created with a plasma thruster aimed at the air intake geometry, so the compression (ratio between throat density and freestream density) and efficiency (ratio between outlet mass flux and inlet mass flux) of the intake system can be measured. Results from the laboratory testing reveal a compression ratio of $\nu = 199.1$, in line with compression results on similar geometries from the literature [6-8], and an efficiency of $\tau = 0.0495$, showing the decrease in efficiency due to the addition of a long discharge channel at the throat of the intake.

Concurrently, SPARTA DSMC [9], a numerical code based on the DSMC methodology [10], has been employed for numerical simulations. A set of initial and boundary conditions and a simulation setup have been adjusted to replicate the flow conditions in the vacuum facility at the Von Karman Institute. Results from experiments and simulations have been meticulously compared to assess the accuracy of the numerical model, showing a discrepancy of 1.22% in efficiency and 27.8% in compression.

Finally, the numerical setup has been compared with results [3] obtained from the DSMC code dsmcFoam+ [11] in order to cross-validate numerical results of intake efficiency. For an intake design with efficiency of $\tau = 0.45$, the validated setup yields a value of $\tau = 0.4512$, thus resulting in a percentage error of 0.26%, demonstrating the fidelity of results.

[1] K. Hohman, et al. `https://www.nasa.gov/wp-content/uploads/2023/12/niac-2011-phi-hohman-atmosphericele pdf`
[2] K. Fujita, et al. `https://doi.org/10.1299/kikaib.70.3038`
[3] C. Rapisarda et al. `https://doi.org/10.1016/j.actaastro.2022.09.047`
[4] P. Parodi, et al. `https://doi.org/10.2514/6.2024-2710`
[5] P. Jorge, et al. `https://doi.org/10.13009/EUCASS2022-7334`

[6] F. Romano, et al. https://www.researchgate.net/publication279975953_Air-Intake_Design_Investigation_for_an_Air-Breathing_Electric_Propulsion_System
[7] F. Romano, et al., https://doi.org/10.1016/j.actaastro.2021.06.033
[8] J. Wu, et al. https://doi.org/10.1016/j.paerosci.2022.100848
[9] S. J. Plimpton, et al. https://doi.org/10.1063/1.5108534
[10] G. A. Bird. The DSMC Method Version 1.2. ISBN 9781492112907, 2013.
[11] C. White, et al. https://doi.org/10.1016/j.cpc.2017.09.030