
Abstract
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Title

Quick-preliminary aerodynamic estimation for a distributed propulsion aircraft with propellers in front of the wing

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Abstract

Distributed electric propulsion (DEP) is an emerging and disruptive technology with a promising potential to reduce energy consumption and emissions. The use of DEP concepts leads to new multidisciplinary interactions between the propulsion system and the lifting surfaces.

Through an adequate preliminary design and analysis, these aero-propulsive synergistic effects can be exploited to increase the overall robustness, capacities, and system efficiency [1]. In this sense, several studies have already shown the possibility to use differential thrust propellers in front of the wing to provide lateral control [2], [3], or as hyper-lifting devices [4].

Within this context, a mid-fidelity tool able to estimate quickly the aerodynamic forces and moments while taking into account the effects of the aero-propulsive interaction would be useful for the preliminary design and analysis of this kind of aircraft.

To address this purpose, an aerodynamic modeling is proposed and built in Python. The module makes use of a pre-generated aerodynamic database produced with a Vortex Lattice Method (VLM). The aerodynamic coefficients are later treated and modified through several surrogate models to account for the aero-propulsive interaction.

For validating the proposed modeling, two aerodynamic analyses conducted by NASA on the X-57 experimental aircraft are chosen. The X-57 mounts twelve electric propellers in the wing's leading edge, meant to act as high lift propellers (HLP), providing propulsion and augmented lift during take-off and landing procedures. The module's results are faced against two Reynolds-averaged Navier Stokes (RANS) flow solvers, for two different flight conditions [5], [6]. The first one is a regular cruise case, whereas the second one tackles a given point within a landing procedure, where the deployment of a Fowler flap together with the augmented lift capacities supplied by the aero-propulsive interaction are meant to provide the required lift. Results prove to be sufficiently good for the use of this modeling for preliminary design and analysis purposes. In particular, for the powered analysis, the lift coefficient can be estimated with a precision that is kept within 7% for all the pre-stall linear region. The computation time is drastically reduced when compared with the CFD analysis, rendering the module suitable for an OAD optimization loop.

Further validation regarding the behavior of the pitch moment is ongoing, which will open the door to a dynamic analysis of the landing procedure. In particular, this flight phase could be performed with different combinations of flap configurations and thrust settings. To date, there is no guideline tackling how to proceed in a safe and easy-to-pilot way, especially regarding an eventual later go-around maneuver.

References

[1] Kim, H.D., Perry, A.T., Ansell, P.J.: A review of distributed electric propulsion concepts for air vehicle technology. In: AIAA/IEEE Electric Aircraft Technologies Symposium (EATS), vol.2018, pp. 1–21. IEEE (2018). https://doi.org/10.2514/6.2018-4998
[2] Nguyen Van, E., Alazard, D., Pastor, P., Döll, C.: Towards an aircraft with reduced lateral static stability using differential thrust. In: 2018 Aviation Technology, Integration, and Operations Conference, p. 3209 (2018a). https://doi.org/10.2514/6.2018- 3209
[3] E. Nguyen Van., Lateral stability and control of an aircraft equipped with a small vertical tail by differential use of the propulsion systems. Use of co-design methods., Thèse de doctorat, ISAE-SUPAERO Institut Supérieur de l’Aéronautique et de l’Espace, Toulouse, France (Oct. 2020).
[4] M. D. Patterson, Conceptual Design of High-Lift Propeller Systems for Small Electric Aircraft, P.hD Thesis, Georgia Institute of Technology, Georgia, USA (Aug. 2016).
[5] K. Deere, J. Viken, S. Viken, M. Carter, M. Wiese, and N. Farr, “Computational Analysis of a Wing Designed for the X-57 Distributed Electric Propulsion Aircraft,” AIAA Aviation 2017 Forum, p. 3923, 2017
[6] J. Duensing, J. Housman, D. Maldonado , J. Jensen, C. Kiris et S. Yoo , Computational Simulations of Electric Propulsion Aircraft: the X-57 Maxwell (2019).