The Experimental Investigation of The Influence of Wing-Propeller Interference – a Case Study

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Recently, small UAVs have seen a stark rise both in military and civil applications. They are performing remote sensing, delivery of goods, search and rescue etc., and the civil drone market is expected to reach $45 Billion[1]. Because of this the question of improving the performance of this class of airplanes has become relevant.

One of the ways of improving aircraft performance is distributed propulsion, a concept which makes use of positive wing-propeller interference. Especially Distributed Electric Propulsion seems prosperous in UAV applications[2]. Unfortunately, there are not many papers investigating the wing-propeller interference in a context of small UAVs. This case study aims to fill this knowledge gap and estimate the possible gains in aircraft aerodynamic efficiency, maximum speed and take-off speed due aforementioned concept.

This article describes experimental investigation of the influence of propellers on Lift and Drag characteristics of the airplane for low stream speeds and different Angles of Attack.

The UAV used in the experiment is the Micro-class aircraft designed for SAE Aero Design 2023 competition by SMKN SAE AeroDesign Student Scientific Club. The aircraft has delta wing and two counter rotating propellers of large diameter when compared to wingspan, which positively influence the roll stability and maximum lift coefficient of the aircraft and have become the subject of this study. Investigated UAV boasts a lightweight airframe weighing 1.84 kg and is able to lift as much as 1.88 kg payload of large volume all while taking off from a 2.4 m long table, meaning that it is possible to hand-launch this aircraft. Reaching 24 m/s of top-speed, it is a good representation of a practical small UAV design.

Results of preliminary examination for non-equilibrium conditions (pitching moment is non-zero) are presented in figure 1. Large Angle of Atack, as well as a large area of separated flow present in this case represents typical takeoff conditions of the examined aircraft. This results indicate that Lift can be significantly improved thanks to a correct placement of propellers, which could enable drones with high wing loading to be hand-launched, thus allowing more payload in off-airfield operations.

This article contributes to closing the knowledge gap regarding the wing propeller interference in context of small UAV with large wing-sweep. Conducted study provides estimation of possible aerodynamic gains in cruise and takeoff conditions. Last but not least it furnishes an experimental insight into a flow around an airplane using vortex lift in a presence of large propellers, a problem which is notoriously hard to solve using numerical methods. Thus, it can serve for validation purposes.

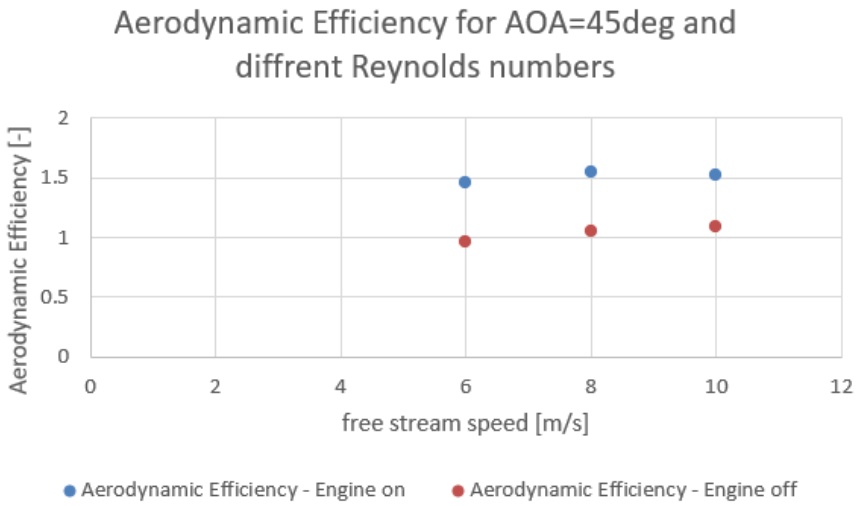

Figure 1 Results of preliminary experiments

Figure 2 The investigated airplane on the test-stand

[1] H. Shakhatreh *et al.*, "Unmanned Aerial Vehicles (UAVs): A Survey on Civil Applications and Key Research Challenges," *IEEE Access*, vol. 7, pp. 48572–48634, 2019, doi: 10.1109/ACCESS.2019.2909530.

[2] M. T. Fard, J. He, H. Huang, and Y. Cao, "Aircraft Distributed Electric Propulsion Technologies - A Review," *IEEE Trans. Transp. Electrif.*, vol. 8, no. 4, pp. 4067–4090, 2022, doi: 10.1109/TTE.2022.3197332.