Computational Aerodynamic Study and Optimization of Parametrically Designed Winglets for a Multirole Unmanned Aerial Vehicle, in Single and Multiphase Flow and Comparison With Experimental Wind Tunnel Results

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1. Introduction

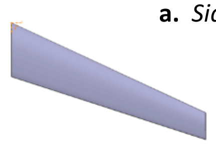
At first, the wing and five winglets for the UAV ethERAs, were parametrically designed using CATIA V5. Next, a Poly-Hexcore mesh was created using the Mosaic Meshing technology of ANSYS Fluent Meshing.

A CFD study was conducted, using the SST k-ω turbulence model, to find the optimal geometry for the usual flying conditions (20 m/s and 0°). After that, the optimal geometry was compared to the Simple wing for various velocities and angles of attack. In addition, the two-phase flow was computationally studied using air-anthracite particle flow, to simulate the flight over wildfire.

Finally, experiments were conducted to validate the results, using a wind tunnel, a force balance and a 3D printed scale model of the optimal wing. The two-phase flow was simulated using air-sand particle flow, for safety reasons.

2. Geometry

a. *Side View.*

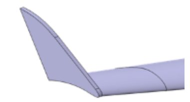


b. *Top View.*

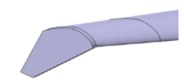
c. *Back View.*

The wing of ethERAs (or Simple) and the five winglets that where designed.

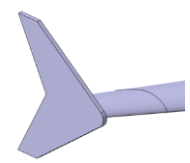
1. *Thin Up.*



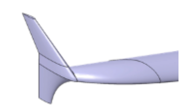
2. *Thin Down.*



3. *Thin Fence.*

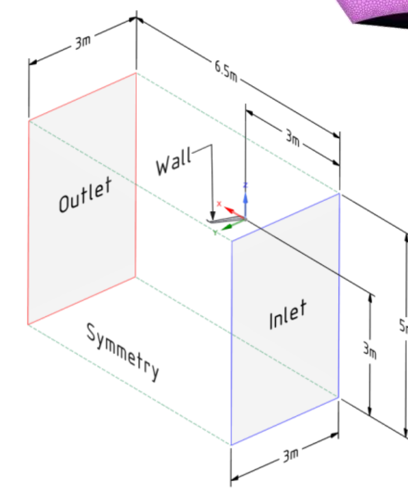


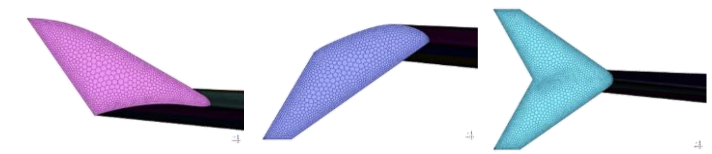
4. *Fence.*

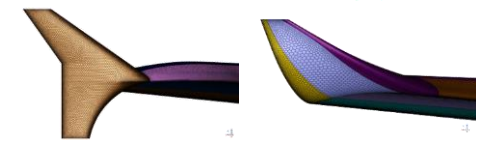


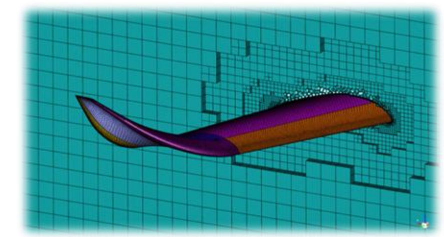
5. *Blended.*

3. Mesh







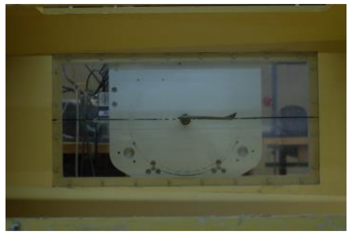


Poly-hexcore mesh of Mosaic technology.

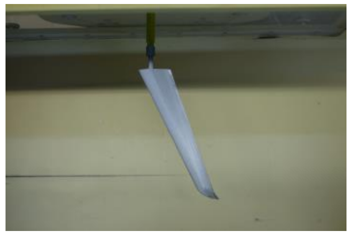
4. Experiment

Wind tunnel.

Iso view.



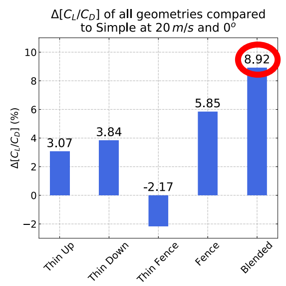
Side view.

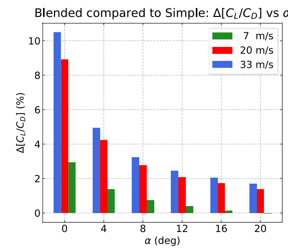


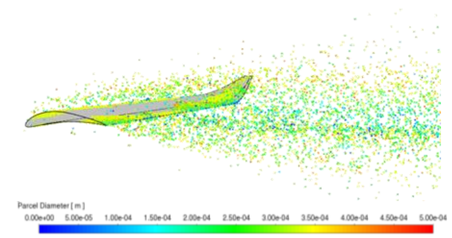
Top view.

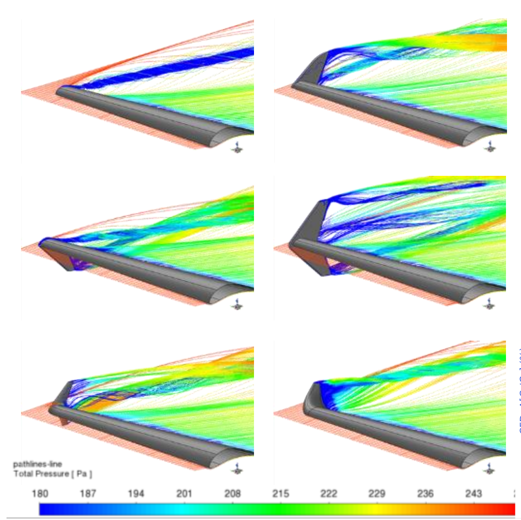
Air-sand particle two-phase flow.

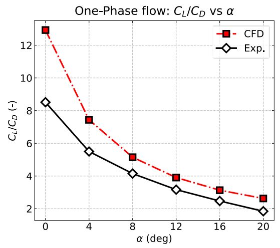
5. Results

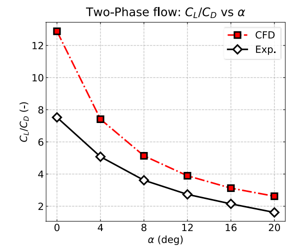


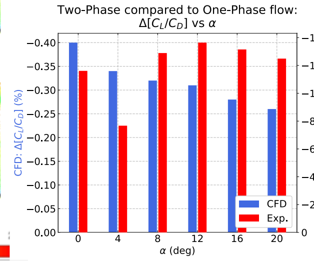


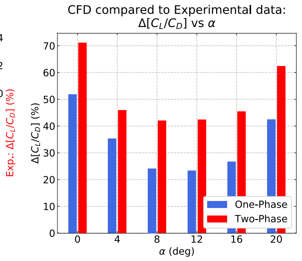












6. Conclusions

Most of the winglets seem to reduce the size of the wingtip vortex, resulting in a lower induced drag. Moreover, the Blended winglet proves to be the optimal, as it shows the highest aerodynamic efficiency (C_L/C_D), which is 8.92% higher than that of Simple, for the usual flying conditions. It also performs better than Simple, for every velocity and angle of attack that was studied.

The CFD simulations seem to be in accordance with the experimental results, despite some slight deviations. These are due to multiple factors including wind tunnel vibrations that affected the force balance, and not achieving the proper experimental velocity for the desired Reynolds number.

Overall, the two-phase flow seems to reduce the aerodynamic efficiency, but more in experiments than in CFD simulations. The discrepancy is due to the aforementioned factors, in addition to the different choice of materials for the solid particles (anthracite and sand), and the experimental setup that disturbed the incoming flow of air.

We can conclude that CFD simulations are a powerful tool to draw faster and cheaper conclusions, the flight over wildfire reduces the aerodynamic efficiency, and the Blended winglet is the optimal choice for the UAV ethERAs.