Design, Analysis and Optimization of a UAV wing.

Diploma Thesis, October 2022

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Summary

This thesis is a study for the design and optimization of a small wing, which will satisfy specific requirements for the mission of an unmanned aerial vehicle. In the design process, the determination of the initial individual values of the construction weight of the air vehicle was carried out by an iterative procedure and the accurate calculation of the wing loading and power loading, W/S and W/P respectively, was estimated by a geometric method. Then aerodynamic analyses was carried out using the Finite Element Method (FEM) in ANSYS FLUENT software. The model with the initial approximation of the position and dimensions of the internal and external structures of the wing was designed in CATIA V5.Optimization of the structure led to the parameterization process of all wing parts and Optimal values for the position and thickness of the internal composite structures (ribs, spars, skin) were determined. A reduction of the structure weight from the initial aluminum wing configuration of up to 60% was achieved.

Conclusions

The number of ribs was reduced from 10 to 4 and their primary role turned out to be the stability of the skin. The optimum spar location and dimensions were determined using the MIDACO solver optimization algorithm. The position of the spars turned out to be ideal closer to the leading and trailing edge of the wing. The symmetric laminate [90/0/-45/45]s with a lamina thickness of 0.125 mm was applied to the skin. In addition, in the spars the symmetrical structure [-45/45]2s was applied to withstand the shear stresses and loads of the wing. With the above methods the final weight, of the configuration of both wings was found to be 2.768 kg which showed a reduction from the original configuration of up to 59.48%

Conceptual design

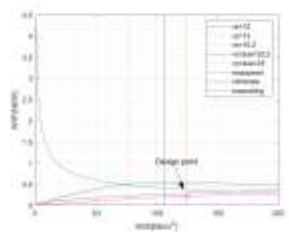


Figure 1. Matching plot.

The optimum design point is marked with the text arrow in the Matlab plot and the exact power loading and wing loading values are 0.21N/W, 124.5 N/W.

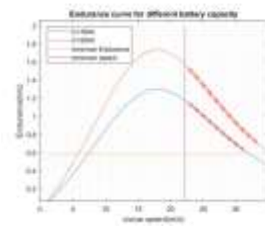


Figure 2. Endurance curve.

To optimize the Endurance flight speed is calculated 23 m/s and the battery pack that is used in the experimental UAV is Turnigy High Capacity 20,000mAh 6S 12C Lipo Pack w/XT90 with a mass of 1.775 kg which is inside the initial guess of battery mass.

Figure 3. Rate of climb curve.

For a cruise speed v=23 m/s the climb (vertical velocity) is Vv=4.27 m/s. This value satisfies the mission requirement for a ***Rate of Climb ≥ 4m/s***

Power specifications

The AXI 4130/20 brushless electric motor is sufficient to provide the required power.

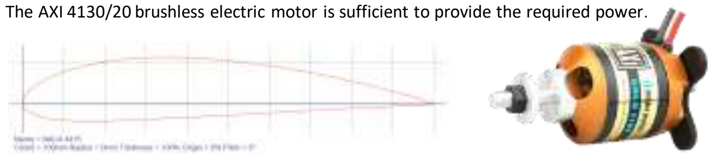


Figure 4. AXI 4030/20 electric motor and airfoil NACA 4415.

Preliminary Design

The wing's external and internal structure are illustrated below, while the front and rear spar are changing position to chord length.

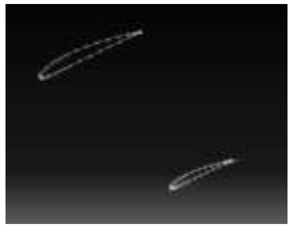


Figure 5. Imported airfoil coordinates.

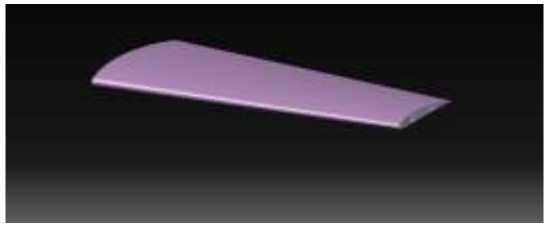


Figure 6. Wing's skin.

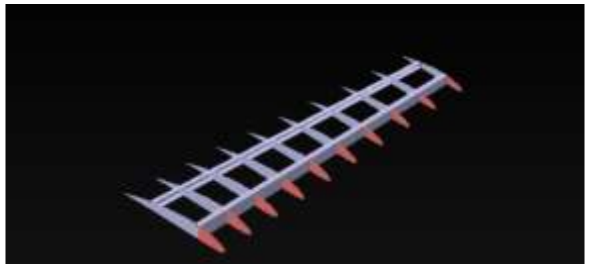


Figure 7. Internal wing's structure.

Aerodynamic Analysis

Aerodynamic analysis was performed in ANSYS FLUENT. The geometry and the isometric view of the meshed model are presented.

Figure 8. Wing and fluid domain geometry.

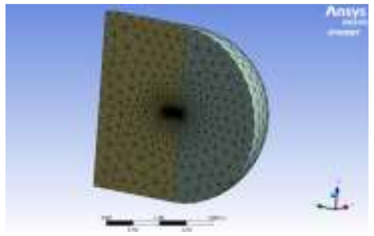


Figure 9. Meshed geometry.

The aerodynamic results are presented through contours and validation diagrams.

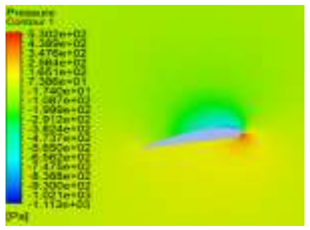


Figure 10. Pressure contour at 10-degree AoA.

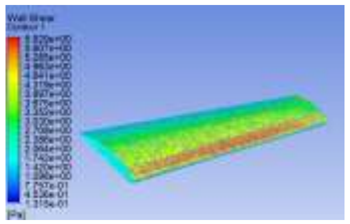
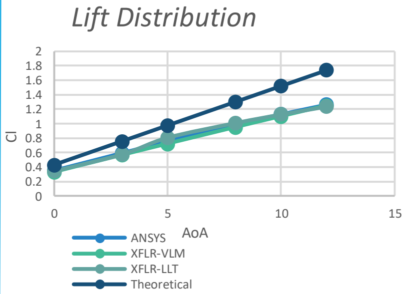
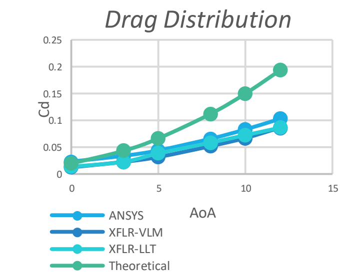


Figure 11. Shear stress of the wing.





Structural Analysis and Optimization Results

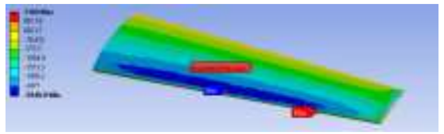


Figure 12. Imported pressure.

The problem is a fluid structure interaction analysis(FSI)
Boundary condition: Imported pressure at 10 degree.

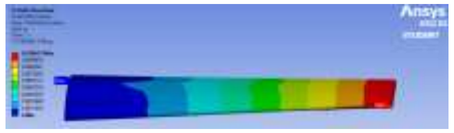


Figure 13. Total deformation.

Total deformation of the composite wing is 10.65 mm

Figure 14. IRF of the composite parts.

Maximum Inverse Reverse Factor appears in the front spar with a value of 0.882

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