https://doi.org/10.31705/BPRM.v5(1).2025.9

Investigation of Aerodynamics of Morphing Wing-Tip Device for Fixed Wing UAVs

Importance of Morphing Wing-tip Device

Unmanned Aerial Vehicles (UAVs) have emerged as one of the major trends in the aviation sector due to their simplicity and low operation cost. UAVs are used for many applications including military applications like surveillance, assaults, and security as well as civil applications like agriculture, delivery, and photography. By 2028, the UAV industry is expected to have grown from its 2022 valuation of USD 32 billion to USD 72 [1]. Minor enhancements in their performance, such as efficiency and operation time, can have a significant positive impact.

For fixed wing UAVs, the wing of the UAV is the main part that generates the lift required to fly the UAVs. The wing generates the lift using the pressure difference between the upper and lower surface of the wing. Wing-tip vortices are an inevitable phenomenon brought on by this pressure differential. These wingtip vortices increase the drag of the wing. Studies on transport aircraft show that approximately 40% of the total drag while cruising is generated by wingtip vortices [2]. To reduce drag generation, several types of fixed wing-tip devices have been employed on the aircraft over the past few decades.

However, fixed shaped wingtip devices were designed to be efficient for one specific flight condition. A morphing wing tip, on the other hand, can alter its shape and adapt for changing flight conditions or stages of flight. Many studies have been conducted to examine the morphing wingtip designed for commercial aircraft and demonstrate that these wing tips can greatly increase the aircraft's overall aerodynamic efficiency. This concept can be incorporated into wingtip of UAV to improve adaptability according to flight condition and used as a control surface to induce rolling which improves the maneuverability of the UAV.

Performance of Morphing Wingtip Device

In our study, we focused on designing and evaluating the performance of a morphing wingtip device that can change the cant angle, for existing fixed wing UAV shown in Figure 1. Also, the potential of using morphing wingtip as a control surface to induce rolling moment was evaluated.

Figure 1: Existing UAV Design

Blended type morphing wingtip that capable of changing the cant angle was selected for study. The geometry of wingtip design was determined from the existing literature and modified according to the dimensions of existing UAV. Then the wingtip device was modeled with wing of the UAV using CAD software as shown in Figure 2(b).

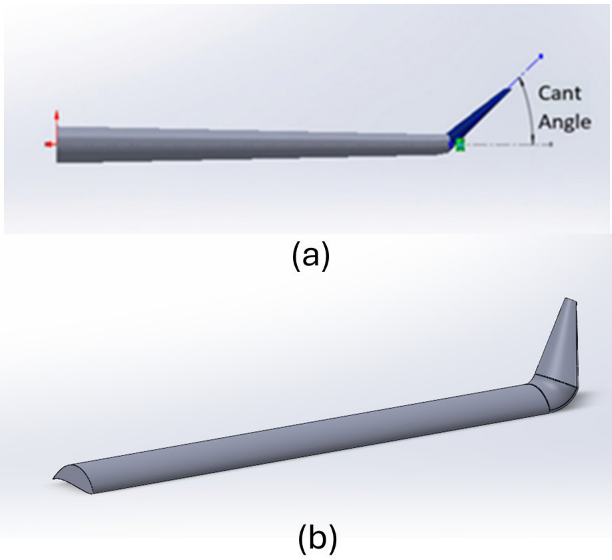

Figure 2: (a) Cant angle of wingtip, (b) Blended type morphing wingtip attached to wing (3D Model)

Computational Fluid Dynamic (CFD) study was conducted on the wingtip attached wing of the UAV and determine its aerodynamic performance with cant angles variation. To identify the aerodynamic characteristics, lift and drag coefficients were used. CFD simulations were conducted for 10 different cant angles of wingtip and 8 different Angles of attack of the air flow for each configuration. The air flow speed is 15 m/s same as the cruising speed of UAV.

From the results shown in Figure 3 and 4, we can clearly see that there is a clear variation of lift and drag with cant angle change. 30° cant angle clearly shows highest lift coefficient value and -90° cant angle shows the least lift coefficient value for most of the Angles of attack. The CFD result was validated using wind tunnel test conducted on scaled-down wing model and comparing the lift and drag coefficient with CFD results.

Rolling Rate Analysis

Another CFD analysis was conducted on wing with different wingtip cant angles configurations at ends as shown in Figure 4, to study the potential of using morphing wingtip as control surface. In this analysis, the cant angles of 30° and -90° are used in ends of wing as they were the maximum and minimum lift generating configurations. From this configuration, a maximum of 50 degrees per second rolling rate can be achieved. By changing the cant angles at ends, less moment and rolling rates can be generated, enabling more controlled and precise maneuvers.

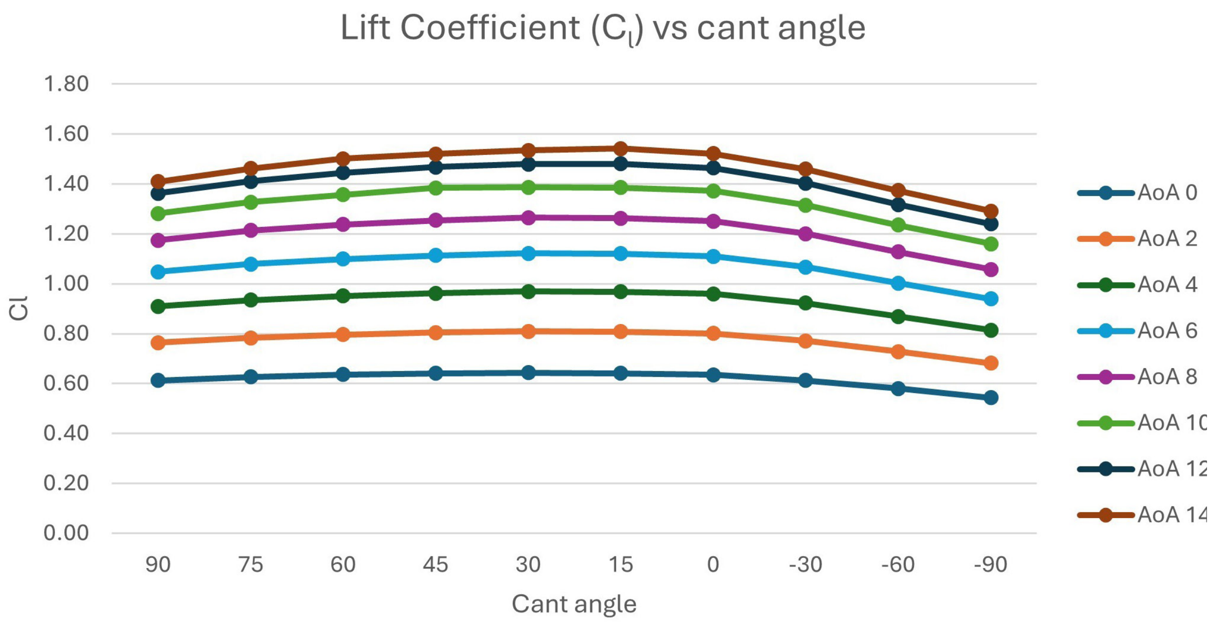

Figure 3: Lift Coefficient vs Cant angle

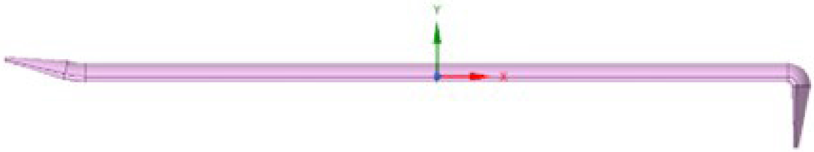

Figure 4: wing with +30° and -90° cant angle wingtips in ends

Conclusion

Morphing wingtip devices could play a crucial role in improving the efficiency of the UAV as it can manipulate the aerodynamic forces like lift and drag up to 16% and 19%. Also, as morphing wingtip can achieve a high rolling rate, it shows potential to function as control surface and improve maneuverability of UAV. By improving the efficiency of a fixed wing UAV, operation time, distance can be improved and reduce energy consumption. This improvement contributes to evolving the UAV industry in many fields as it becomes economical.

References:

[1] K. L. Pham, J. Leuchter, R. Bystricky, M. Andrle, N. N. Pham, and V. T. Pham, "The Study of Electrical Energy Power Supply System for UAVs Based on the Energy Storage Technology," Aerospace, vol. 9, no. 9, Sep. 2022, doi: 10.3390/aerospace9090500.

[2] D. Liu, B. Song, W. Yang, X. Yang, D. Xue, and X. Lang, "A Brief Review on Aerodynamic Performance of Wingtip Slots and Research Prospect," Nov. 01, 2021, Springer. doi: 10.1007/s42235-021-00116-6.

Article by

Heshan De Silva, Viran Lokugalappaththi, Sineth Ranasingha

Department of Mechanical Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka.