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Design and Analysis of UCAV Wing with a without Winglet by Varying the Cant Angle

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***Abstract*—Winglet are small extension of wing. Which is attached to wing structure at the root tip with appropriate cant angle.**

The main aim of this project is to implement a suitable winglet to a UCAV wing and improve the performance and efficiency of UCAV wing by reducing a drag due to lift and increase lift to drag ratio.

The wing of 10m span length and a NACA 6 digit series of airfoil section are considered. This airfoil has lower drag at higher speed when compared to 4 or 5 digits series. Among these airfoils NACA 64A210 has been chosen for the UCAV wing. For this UCAV wing the winglet has been designed using CATIA V5R20. Here designing has been done for winglet parameters in five cases by varying the cant angles i.e. 5°, 22.5°, 45°, 67.5°, and 90° for this different cant angle the CFD flow analysis were carried out by using ANSYS V14.5.

Now a results of UCAV wing with and without winglet are compared with graph of aerodynamic parameters such as C_l, C_d and C_l/C_d with varying AOA at different velocities.

Keywords: Unmanned Aerial Vehicles (UAVs), Unmanned Combat Aerial Vehicle (UCAV), Angle of attack (AOA), Computational Fluid dynamics (CFD), National Advisory committee for aeronautics (NACA), Coefficient of lift (C_l), Coefficient of drag (C_d).

I INTRODUCTION

A. Unmanned Aerial Vehicles (UAV)

A flying dream of human beings, was experimented by a Turkish scientist Hezarfen Ahmet Çelebi as early as 1630 with homemade wings from the top of the Galata Tower to Doğancılar Square above Üsküdar in İstanbul [1]. Even in those days after this brave move, people believed that flying was not just a dream. Afterwards, lots of attempts had been made by people to attain this enjoying experience.

In 1804 George Cayley flew the first fixed wing unmanned model glider in Yorkshire, England. Later, John Stringfellow performed the first flight of a powered unmanned aircraft, with a 12-foot spanned wing [2].

B. Unmanned Combat Aerial Vehicle (UCAV)

Unmanned combat air vehicle (UCAV) is a class of unmanned aerial vehicle (UAV). Like UAVs, UCAVs can also send observation results to ground stations. They differ from ordinary UAVs, because they are also designed to deliver weapons (attack targets) and have higher agility, possibly with a great degree of autonomy [3].

UCAVs are also capable of flying without risking a human life onboard. Moreover, no pilot training will be required to operate these vehicles. Therefore, the range, the endurance, the combat time and the cruise ceiling are only limited with the aircraft performance

Unmanned air vehicles have the advantage that they can challenge high g-loads and therefore include high maneuvering capability. Because they do not have a pilot onboard, the design is limited by the engine performance and the structure. On the other hand, no pilot means no cockpit so cleaner aerodynamic shape, less avionics and as a result a lighter aircraft. In addition, the aircraft can be made stealthier because of the freedom to design a geometry with lower radar cross section.

Current UCAVs are aimed to operate virtually autonomously. They can be programmed with route and target details, and then conduct the mission even without help of human pilots.

B. Winglet

Winglets are small wing like structures at the end of a wing. The purpose of winglets is to improve aerodynamic efficiency of the wings to which they are attached. Research has shown that winglets do in fact improve performance. Research into winglet technology for commercial aviation was pioneered by Richard Whitcomb in the mid 1970’s

Whitcomb’s research focused on applications for large airplanes like the Boeing 737 at a high subsonic airspeed. Research in full size aircraft revealed that winglets can provide improvements in efficiency of more than 7%. Winglets offer greater lift without a greater wingspan. For large airplanes like the Boeing 747, winglets can increase lift while maintaining a fixed maximum wingspan requisite for many international airports. Unmanned Air Vehicles (UAVs) however, generally operate at much lower Reynolds numbers, and UAVs would seem to have little restriction for wingspan. However winglets might offer some benefits to UAVs. A small improvement in efficiency would allow for greater time in flight, a heavier payload, or increased range.

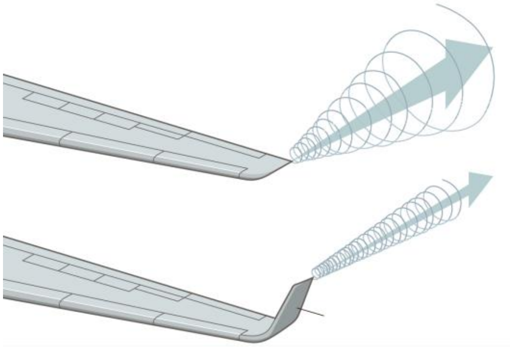
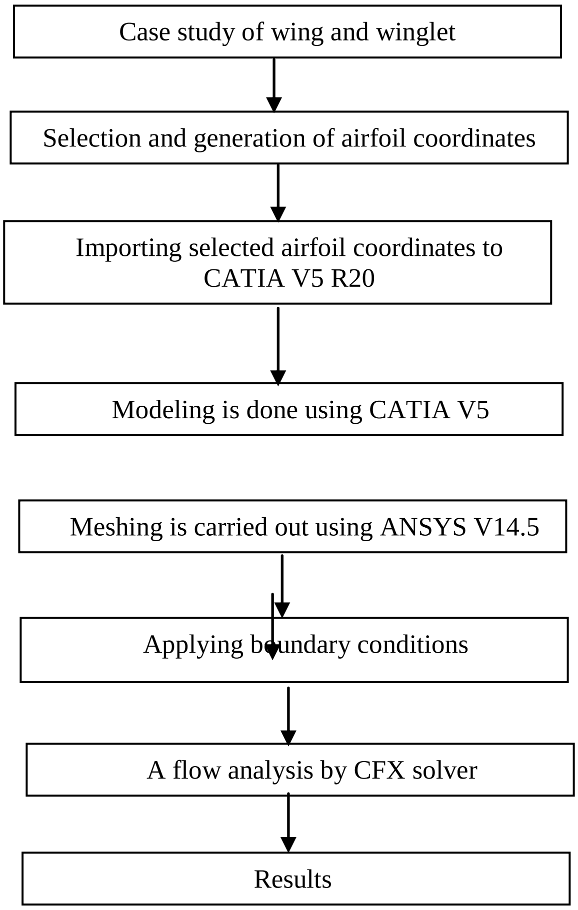


Fig 1. Wing and Winglet [7]

II. METHODOLOGY



The methodology in this by adopts the CATIVA V5R20 for designing of UCAV wing and winglet. Meshing and analysis are done by ANSYS V14.5. Here CFD flow analysis is carried out for both UCAV wing with and without winglet.

A. Design parameters for wing and winglets are as follows:

Wing is designed by using asymmetric airfoil of NACA 6 series i.e. NACA 64A210. This NACA 64A210 airfoil have lower drag at higher speeds compared to four or five digits series. It give the negative lift to the aircraft as shown in below figure 2.1 which is generated using javafoil software.

B. Steps to generate the airfoil coordinates in javafoil

1. Open JAVAFOIL SOFTWARE

2. Enter the name of the airfoil (*eg. NACA 0012*)

3. Enter the number of points to be generated.

4.Using the airfoil nomenclature enter the values for thickness, camber and the camber location.

5. Click on create airfoil to generate the coordinates.

Step 1: Generating airfoil.

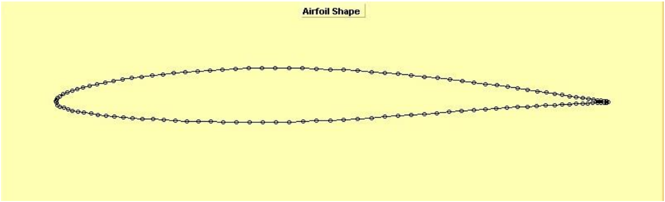


Fig 2. Generating the NACA 64A-210 airfoil coordinates.

Step 2: C_l and C_d graph.

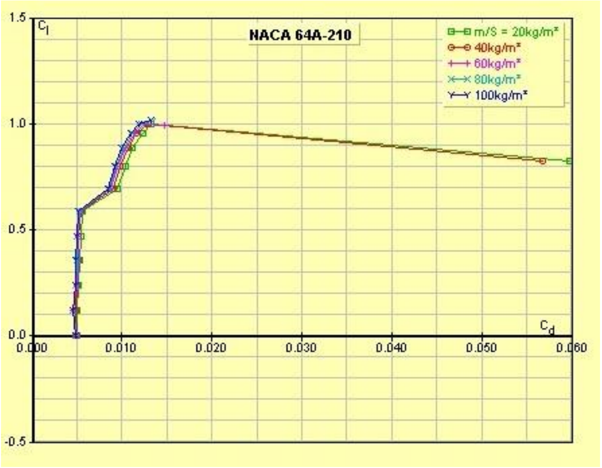


Fig 3. C_l vs C_d graph of NACA 64A-210 airfoil.

Step 3: C_l and AOA graph.

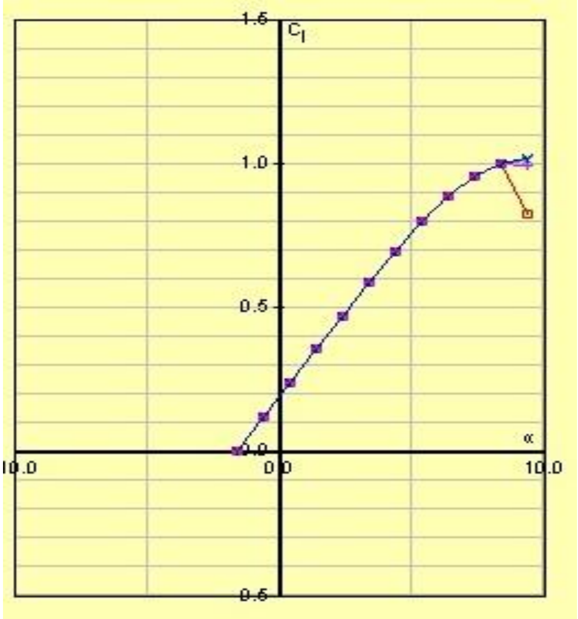


Fig 4. C_l VS AOA graph

Wing has considered here as a taper wing. Taper wing gives the more lift and high speed. Here taper ratio of 0.3 is considered for design. The following figure 5 shows the wing design.

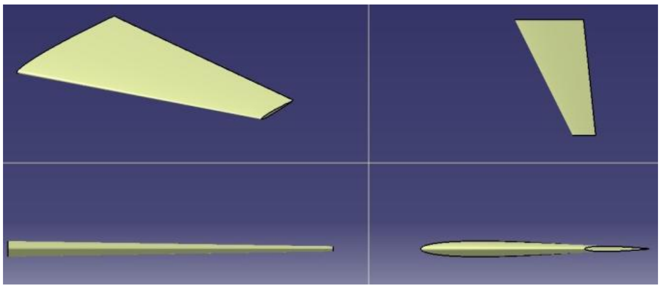


Fig 5. Modeling of Taper wing

Winglet basic parameters are as follows in below figure 6.

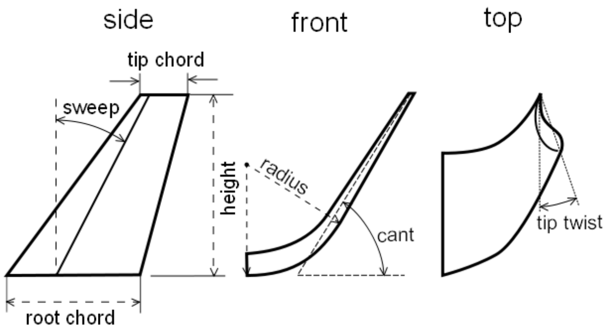


Fig 6. Winglet design parameters.

Winglet are designed for five cases by varying the design parameters as shown in below table 1.

TABLE I WINGLET DESIGN CASES

Cases	b (height)	Cant Angle	sweep	Taper	Tip chord	%
case1	300	90	22.5	0.75	750	0.75
case2	350	67.5	35	0.5	500	0.5
case3	400	45	45	0.5	500	0.5
case4	450	22.5	0	1	1000	1
case5	500	5	0	1	1000	1

Winglet designed in CATIA as shown in below figure 7.

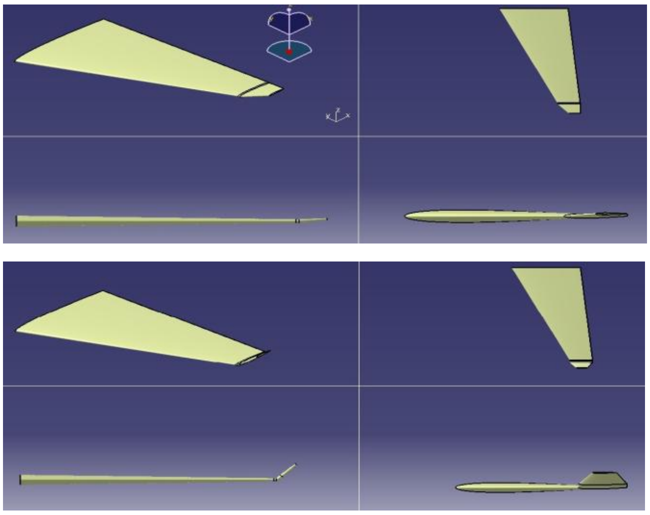


Fig 7. *Winglet design 5° and 45°.*

III. GENERAL PROCEDURE FOR CFD ANALYSIS

TABLE II GENERAL PROCEDURE

No.	Steps	Process
1	Problem statements	Information about the flow
2	Mathematical model	Generate 3D model
3	Mesh generation	Nodes/cells, time instants
4	Space discretization	Coupled ODE/DAE systems
5	Time discretization	Algebraic system Ax=b
6	Iterative solver	Discrete function values
7	CFD software	Implementation, Debugging
8	Simulation run	Parameters, stopping, criteria
9	Post processing	Visualization, analysis of data
10	Verification	Model validation/ adjustment
11	Saving case and data	Save all the obtain data
12	Comparing	Comparing the outcome values

A. Input and boundary conditions

TABLE III BOUNDARY CONDITIONS

Cases	M	V	AOA	u	v	w
1	0.2	68	0	68.0	0	0.0
2	0.2	68	5	67.7	0	5.9
3	0.2	68	10	67.0	0	11.8
4	0.2	68	15	65.7	0	17.6
5	0.7	238	2	237.9	0	8.3

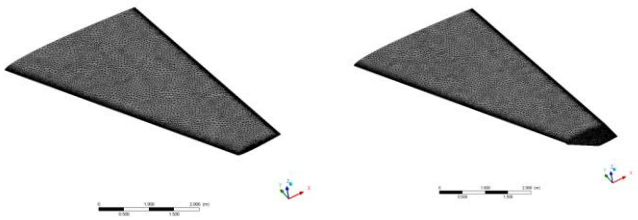
$$u = V^* \cos \alpha \qquad (1)$$

$$v = V^* \sin \alpha \qquad (2)$$

u, v, w are velocity components in x, y, z directions respectively.

IV. MESHING

Mesh generation process is based on FEA model. For analyzing flow, the surface is spilt into number of smaller elements. If the number of elements is more it gives more accurate results. By using TRIA surface mesh, meshing is done. Near the curved surfaces of wing and winglet fine mesh is done this mesh feature makes the mesh to capture properly near the curved surfaces. Meshed wing and winglet as shown in figure 8 and 9.



(i) (ii)

Fig 8. Meshed design (i and ii shows the winglet meshed design of both wing with and without winglet respectively)

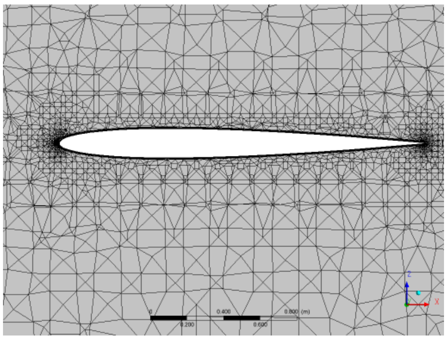


Fig 9. Meshed design

V. RESULTS AND DISCUSSION

Contours of total pressure over UCAV wing with and without winglet for different winglet parameters are as shown in following figures 10, 11, 12, 13, 14 and 15.

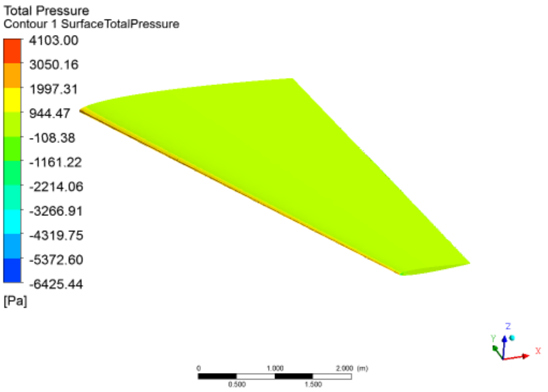


Fig 10. Total pressure over wing without winglet

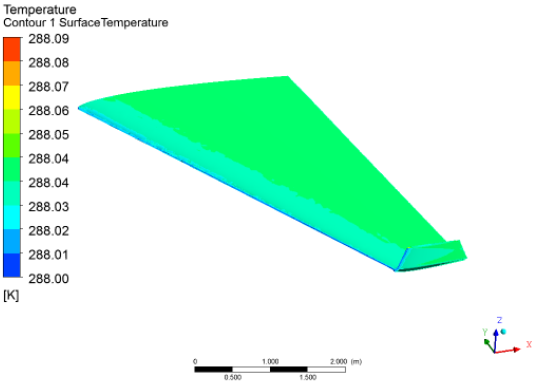


Fig 11. Total pressure over wing winglet of cant angle 90°

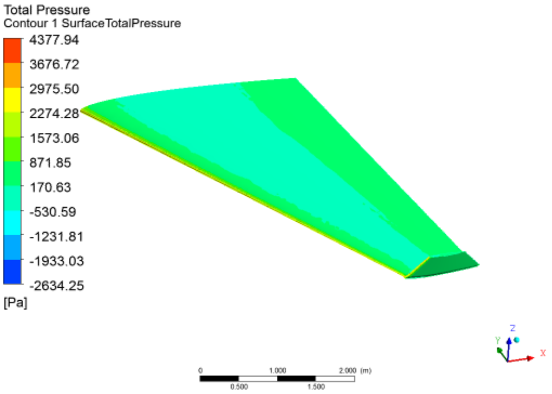


Fig 12. Total pressure over wing winglet of cant angle 67.5°

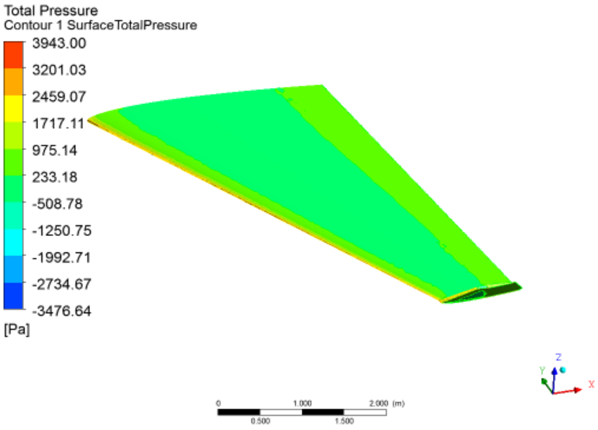


Fig 13. Total pressure over wing winglet of cant angle 45°

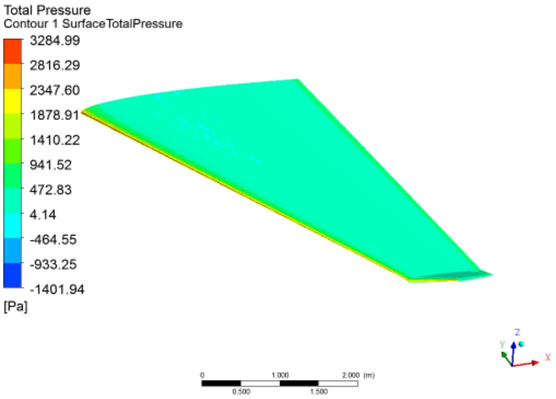


Fig 14. Total pressure over wing winglet of cant angle 22.5°

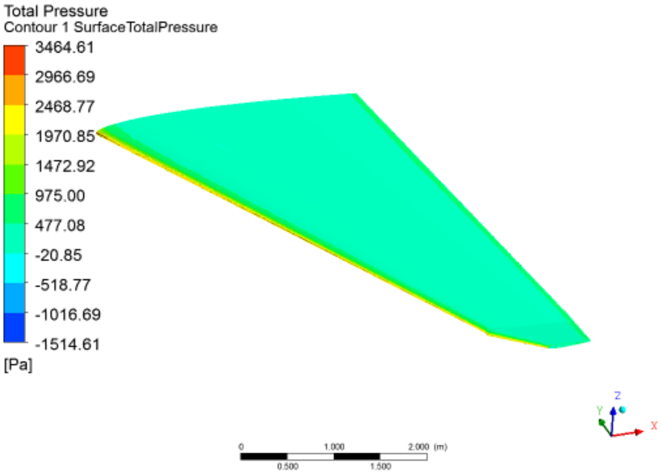


Fig 15. Total pressure over wing winglet of cant angle 5°

A. Graphs

Post processing of the results is carried out. C_d vs AOA, C_l vs AOA and L/D vs AOA of the simulations are generated. Fig. 16, 17 and 18 shows the comparison of wing and winglets.

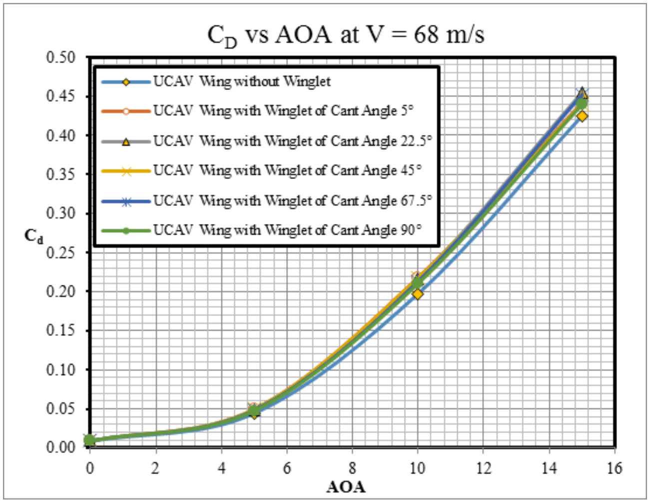


Fig 16. C_d Vs. AOA

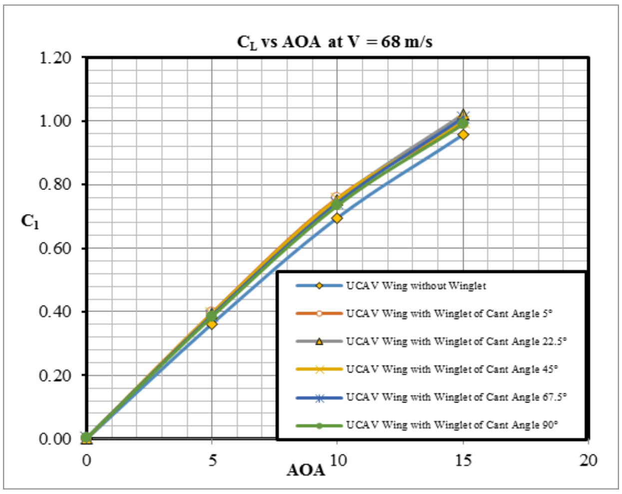


Fig 17. C_l Vs. AOA

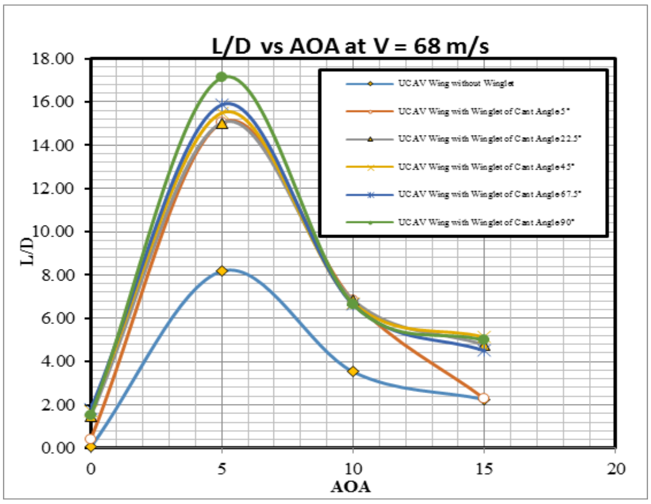


Fig 18. L/D Vs. AOA

VI. CONCLUSION

This project proposes alternatives in the design of winglet. An improved winglet design will significantly yield a better performance of an aircraft and reduce the fuel consumption.

Modification can also be done at this stage by optimizing winglet cant angels for better performance. Here in this project from the observed data the UCAV wing with winglet of cant angel 45° gives the higher lift force as well as the lower drag force. Despite the benefits of winglets, there are some drawbacks that need to be addressed. For example, the bending moment at the wing root is higher, and may require additional structural reinforcement of the wing. Winglets although can produce a low drag wing, they add to the cost and complexity of construction. They also modify the handling and stability characteristics.

FUTURE SCOPE

- A better material can be chosen for static and dynamic analysis for UCAV wing and winglet.
- More over different shape and size of winglet can be designed for this UCAV wing.
- Optimization can be done for the UCAV wing to reduce the weight of wing.

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