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Modeling and CFD Analysis of Flow Over Aircraft Split Winglet and Blended Winglet

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Abstract

A winglet is a device used to improve aircraft efficiency by lowering the induced drag caused by wingtip vortices. A preliminary Computational Fluid dynamics (CFD) study was conducted to compare the wingtip vortices and induced drag generated by different wingtip configurations. The geometry of different winglets was modeled in CATIA and numerically analyses using ANSYS Fluent solver. The results produced detailed contour and streamlines of the wingtip vorticity magnitude created by each wingtip configuration. Using the design tool, two different designs were created one is split and the other is blended winglet and comparison is made from the two configurations and found lift and drag coefficients at different angles of attack.

Key Words: *Computational Fluid dynamics (CFD), ANSYS Fluent, Winglet.*

1. NOMENCLATURE

C	Chord length of airfoil
α	Angle of attack
C_L	Coefficient of lift
C_D	Coefficient of drag
M	Mach Number

2. ABBREVIATIONS

NACA	National advisory committee for aeronautics
CFD	Computational fluid dynamics
AOA	Angle of attack
T.K.E	Turbulence Kinetic Energy

1. INTRODUCTION

The main purpose of any winglet is to improve the aircrafts aerodynamic performance by reducing the induced drag formation at the wing tips. The term winglet was previously used to describe an additional lifting surface on an aircraft. Wingtip devices are usually intended to improve the efficiency of fixed-wing aircraft[1]. There are several types of wingtip devices, and although they function in different manners, the intended effect is always to reduce the aircraft's drag by partial recovery of the tip vortex energy. Wingtip devices can also improve aircraft handling characteristics and enhance safety[2]. Such devices increase the effective aspect ratio of a wing without materially increasing the wingspan. Note that an extension of span would lower lift-induced drag, but would increase parasitic drag and would require boosting the strength and weight of the wing [3]. Generalized aircraft winglet is shown in below figure.1;

Fig1: Aircraft Winglet

1.1 DESCRIPTION OF WINGLETS

Winglets reduce wingtip vortices, the twin tornados formed by the difference between the pressure on the upper surface of an airplane's wing and that on the lower surface. High pressure on the lower surface creates a natural airflow that makes its way to the wingtip and curls upward around it. When flow around the wingtips streams out behind the airplane, a vortex is formed. These twisters represent an energy loss and are strong enough to flip airplanes that blunder into them. Winglets are specially designed extensions adjusted to the wingtip that alter the velocity and pressure field and reduce the induced drag term, thus increasing aerodynamic efficiency [4].

A winglet is a (near) vertical extension of the wing tips. The upward angle of the winglet, its inward angle as well as its size and shape are critical for correct performance – this is why they can look quite different. Air rotating around the wing strikes the surface of the winglet that directs it in another direction – thus creating an extra force, basically converting otherwise waste of energy to thrust. The winglet is cambered and twisted so that the rotating vortex flows at the tip create a lift force on the winglet that has forward component [1]. Winglets provide the greatest benefit when the wing tip vortex is strong, so a low aspect ratio wing will see more advantages from the use of winglet than an already highly efficient high aspect ratio. In the present paper we will discuss about two different winglets i.e. split winglet and blended winglets, and the actual profiles are shown in below fig2 and fig3. These two winglets were considered for NACA 2424 airfoil [7], and it is shown in fig 4.

Fig2: Split winglet

Fig3: Blended winglet

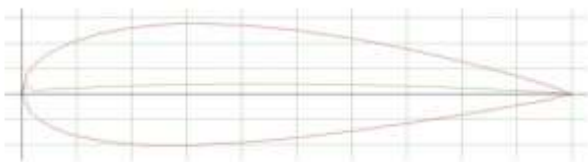

Fig4: NACA 2424 airfoil

1.2 SELECTION OF WINGLET

In this paper we have considered NACA 2424 airfoil with split winglet and blended winglet[5]. Numerical analysis has been carried out for the above mentioned winglets. Therefore, blended winglet having high lift to drag ratio.

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2. MODELLING OF WINGLETS

The following dimensions are considered to design the split winglet and blended winglet.

Tab1: Dimensions of split winglet

Name	Upper surface	Lower surface
Can't angles	38^0	52^0
Sweep angles	15^0	36^0
Span	137	67

Tab2: Dimensions of Blended winglet

Name	Angles
Can't angles	25^0
Sweep angles	10^0
Span	137

The designed winglets with above dimensions are shown in below fig 5 & 6.

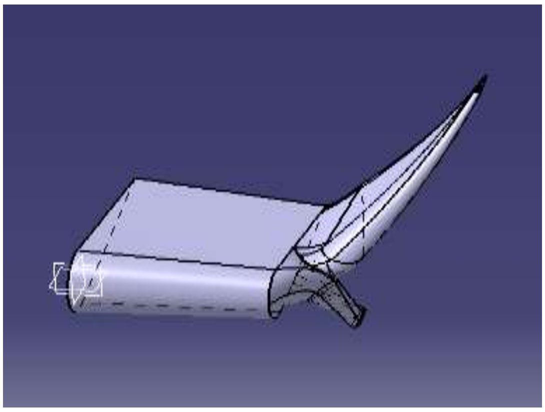

Fig5: Split winglet

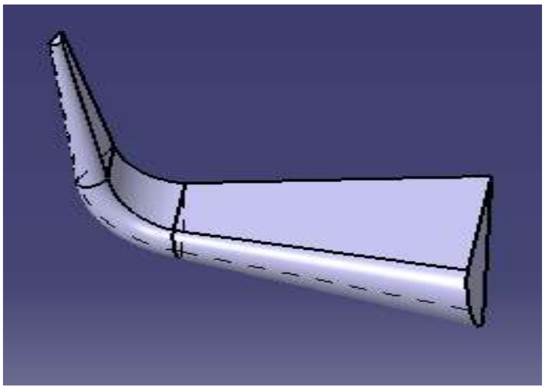

Fig6: Blended winglet

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3. NUMERICAL SIMULATION

For numerical simulations the above mentioned winglets are selected. The 2D computational mesh designed in rectangular type domain. It consists of 32331 elements for split winglet and 21752 elements for blended winglet shown in figure. And simulations are done by ANSYS FLUENT Software. It uses a finite volume method. In this k-ε model is chosen for analysis and for momentum equation second order upwind discretization, for pressure velocity coupling SIMPLE algorithm is chosen for both winglets [6]. Second order upwind discretization is used for turbulence kinetic energy and first order upwind discretization is used for turbulence dissipation rate. Fig 7 & 8 shows the mesh for split and blended winglets.

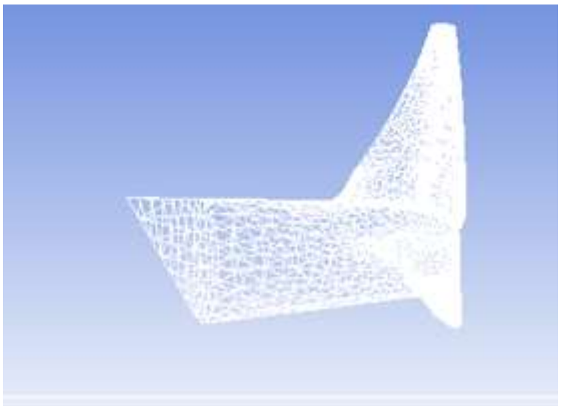

Fig 7: Mesh on Split winglet

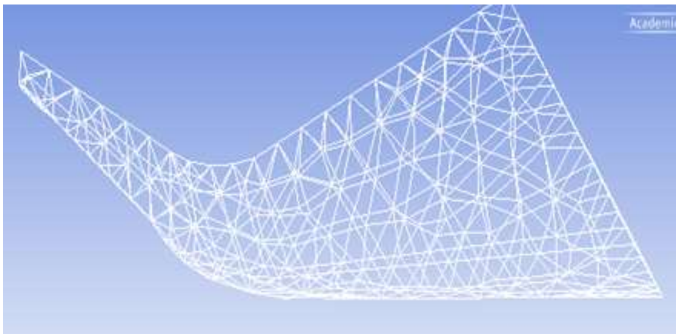

Fig 7: Mesh on Blended winglet

4. RESULTS AND DISCUSSION

The numerical simulation is carried out by considering Mach number 0.6, at different angles of attack, i.e. 10^0 and 15^0. The maximum lift to drag ratios was calculated, which is important parameter for starting of airplane. Based on the results, the correlation between the lift coefficient and drag coefficient is higher, that is drag increases with respect to lift incase of split winglet. But we found that lift to drag ratio is more for blended winglet at angle of attack 10^0. The figure 8 and 9 shows variation of lift and drag coefficients for split and blended winglets with different angle of attack.

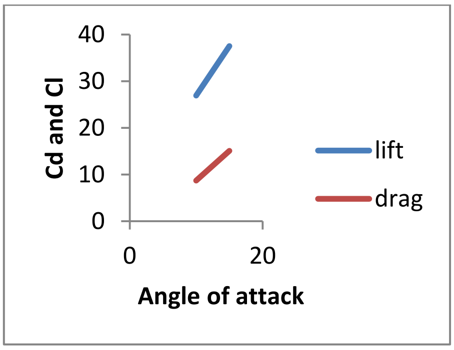

Fig 8: Angle of attack Vs coefficient of lift and drag

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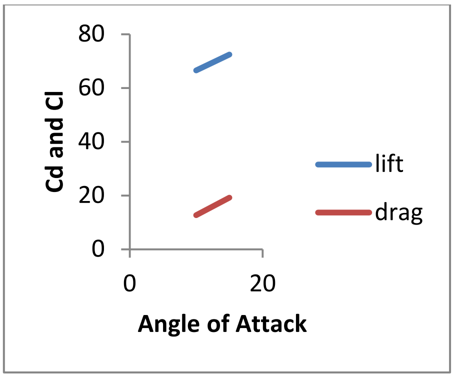

Fig 9: Angle of attack Vs coefficient of lift and drag

The pressure coefficient, velocity coefficient and turbulence kinetic energy coefficient are un-symmetrical at different angle of attack for split and blended winglets. But we observed that at 15 degree angle of attack the pressure coefficient, velocity coefficient and turbulence kinetic energy coefficient are more for blended winglet. The graphical representations are shown below for blended winglet at 15 degree angle of attack.

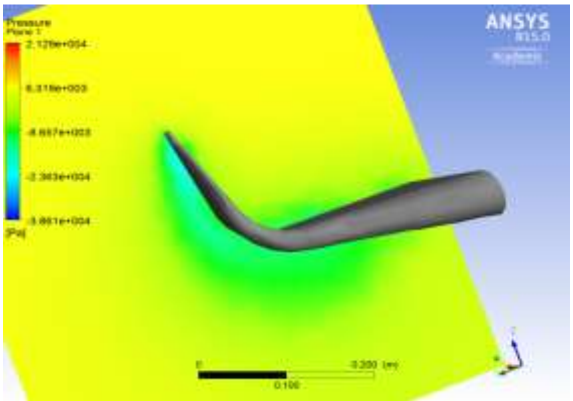

Fig 10: Pressure Coefficient at AOA 15^{0}

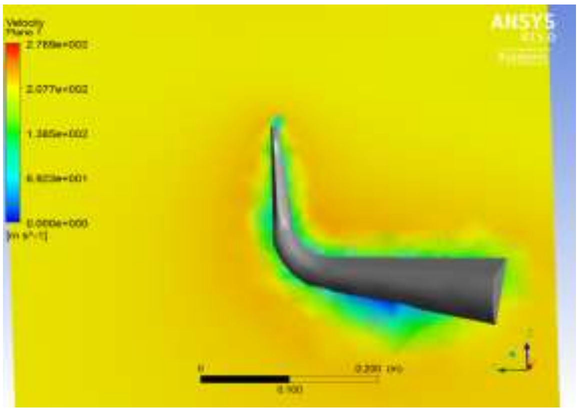

Fig 11: Velocity Coefficient at AOA 15^{0}

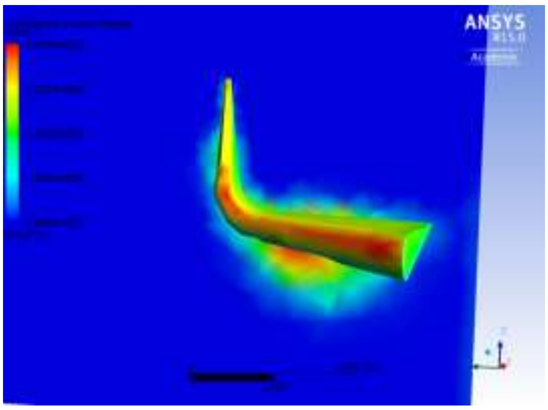

Fig 12: Turbulence kinetic energy Coefficient at AOA 15^{0}

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5. CONCLUSIONS

1. This project proposes that Winglets will significantly yield a better performance of an aircraft and reduce the fuel consumption.
2. The present simulation of split Winglet and blended Winglet cases promises that Winglets installation reduces the tip vortices, which leads to the reduction in induced drag.
3. The correlation between the lift and drag co-efficient are considered for all winglets. The lowest drag coefficient was found for blended winglet [NACA 2424] even at higher lift co-efficient.
4. In this project the lift curve slope increases more with the addition of the blended Winglet at 10^0& 15^0 AOA and at the same time the drag decreases more for the aircraft model with blended Winglet campare to split Winglet.

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