PERFORMANCE ANALYSIS OF WINGLET AT DIFFERENT ANGLE OF ATTACK

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Abstract - *The airflow over the wing of an aircraft generates the lift and drag forces due to the pressure distribution, among all the drag forces the aircraft is majorly affected by the induced drag. The induced drag is an aerodynamic drag force that occurs in airplane due to the separation of boundary layer at the leading edge of the wing and due to the change in the direction of air flow. The induced drag is caused mainly due to the wingtip vortices formed at the wingtips. Wingtip vortices are caused due to the circular airflow which is formed at the end of the wing. Due to the wingtip vortices the airflow over the wing changes its direction and wake is created at the trailing edge of the wing. The induced drag is mainly affected by the angle of attack. As the angle of attack increases the induced drag also increases. In order to reduce the wingtip vortices winglets can be placed at the wingtips which delays the separation of boundary layer from the skin of the aircraft increasing the lift generated at the wingtip and also reduces the lift-induced drag or induced drag which leads in increase of lift to drag ratio.*
In this paper the comparison is made between the results of wing with winglets and is seen for better performance (reduce the induced drag and increase the lift) winglet angle. The wing is been modeled by attaching the blended type of winglet at various angles and then analyzed at different angle of attacks. The modeling is done using catia V5, then is analyzed using fluent in ANSYS.

Key Words: Induced drag, Winglet, Wingtip vortices, Blended winglet

1.INTRODUCTION *(Size 11 , cambria font)*

The induced drag is a different type of drag. It is caused by the pressure imbalance at the tip of a finite wing between its upper (pressure side) and lower (suction side) surfaces. 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. Vortices form because of (U.S Centennial of Flight Commission, n.d) the difference in pressure between the upper and lower surfaces of a wing that is operating at a positive lift. Since pressure is a continuous function, the pressures must become equal at the wing tips. The tendency is for particles of air to move from the lower wing surface around the wing tip to the upper surface (from the region of high pressure to the region of low pressure) so that the pressure becomes equal above and below the wing. The flow is strongest at the wing tips and decreases to zero at the mid span point as evidenced by the flow direction there being parallel to the free stream direction.

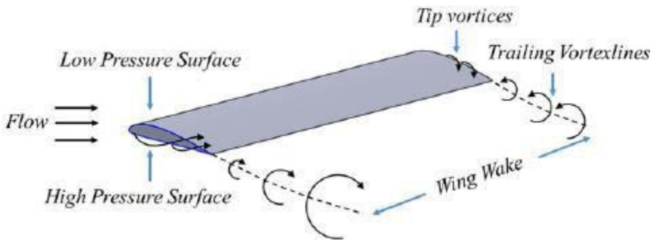

Fig.1: Formation of wingtip vortices

In aerodynamic engineering, drag reduction is a big challenge. To reduce this drag a device called winglet which is placed vertically at set of angle on the end of aircraft wing [1]. Winglet is played very important role in improving the aircraft performance. Aircraft designers are performing research to improve the aircraft efficiency which will be benefit to both aircraft manufacture and the operators. The rise of operational costs has forced industry to improve the efficiency of commercial air transport and this has led to some advanced developments for reducing drag. Several different types of winglet devices have been developed to improve the efficiency and the selection of the winglet device depends on the specific situation and the airplane type.

Winglets improve efficiency by diffusing the shed wingtip vortex, which in turn reduces the drag due to lift and improves the wing's lift over drag ratio Winglets increase the effective aspect ratio of a wing without adding greatly to the structural stress and hence necessary weight of its structure.[2]

2. DESIGN

In this paper the designing of wing and wing with winglet is done using the CATIA V5 software. The blended winglets are attached at the wing tips. The wing is designed using the airfoil shape, which is designed using the design foil software.

2.1 Design of Aerofoil

The **NACA** airfoils are shapes of the cross section of the wing developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA airfoils is described using a series of digits following the word "NACA". The parameters in the numerical code can be entered into equations to precisely generate the cross-section of the airfoil and calculate its properties. The NACA four-digit wing sections define the profile by first digit describing maximum camber as percentage of the chord, second digit describing the distance of maximum camber from the airfoil leading edge in tens of percents of the chord and last two digits describing maximum thickness of the airfoil as percent of the chord. The design foil software helps to know shape of the airfoil. It is designed such that we can create a number of airfoils in this software there are many airfoil data installed in it. The design foil software also enables us to send the airfoil into design software like CATIA or AUTO CAD etc. This software is being used by many companies to generate the shape of the airfoil easily and import that to the design software. The design foil software helps in obtaining the coordinates of the airfoil we required for different chord lengths so that they can be imported into the catia for the generation of airfoil shape.

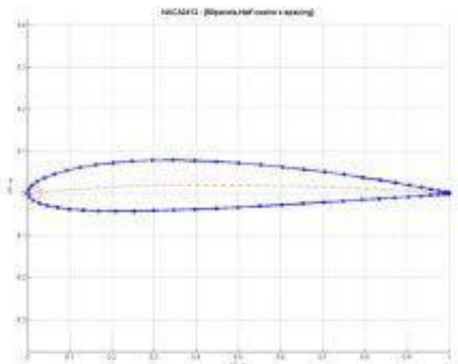

Fig.2: Airfoil coordinates generated using Designfoil software

2.2 Design of wing with winglet at different angles

Importing these coordinates into Catia and designing the wing using the tools as shown in figure. The blended winglet is attached to the wing at 30^0 angle and 90^0 angle as shown in fig3 and fig 4.

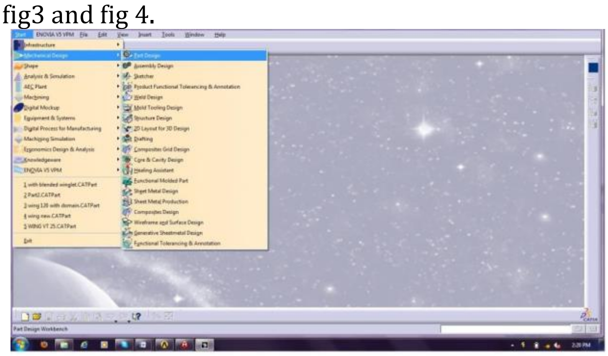

Fig 3: selecting a part design in CATIA

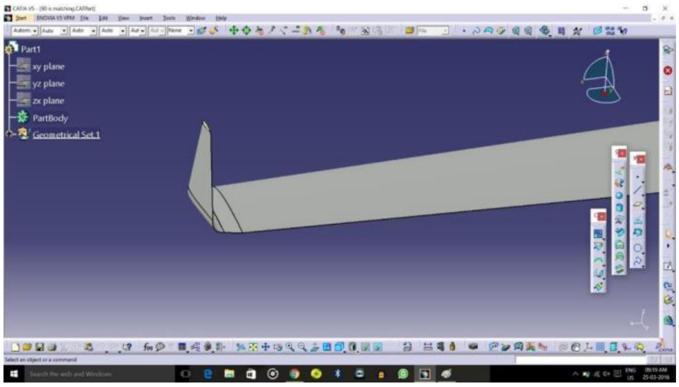

Fig4: Wing with winglet at 90 degrees

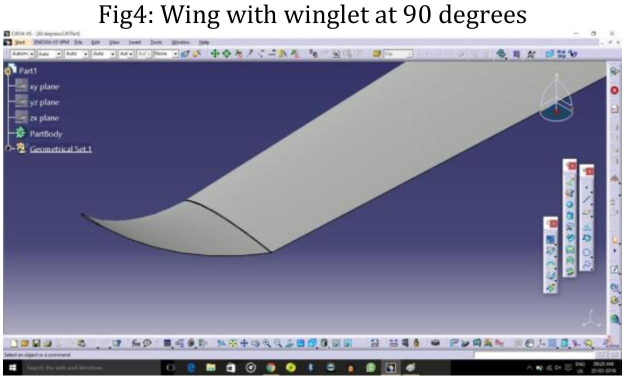

Fig.5: Wing with winglet at 30 degrees

3. ANALYSIS

The analysis is done for all the three wings using the Ansys-Fluent workbench by giving the initial and boundary conditions as pressure inlet and velocity outlet to find the coefficient drag(Cd) for each wing. The flow on the wing without winglet, wing with blended winglet and wing with circular winglet is analyzed and the Cd is estimated.

The figures 6 and 7 shows the boundary conditions applied on the wing with winglet and meshing of the boundary around the wing with winglet.

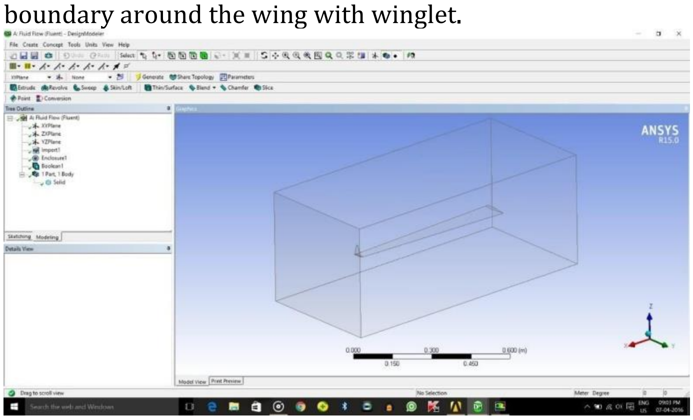

Fig.6: creating the boundary volume around wing

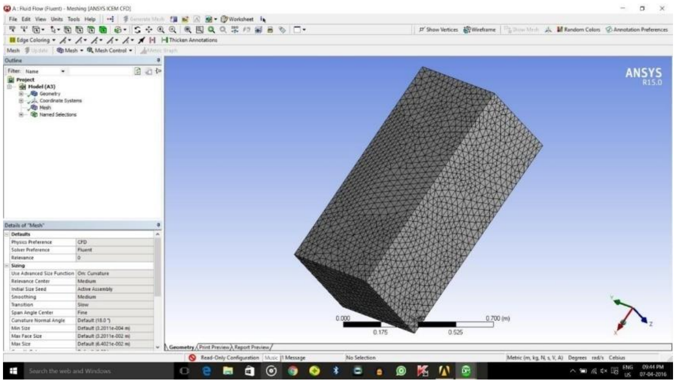

Fig.7: meshing the boundary volume

4. Results and Discussions

After the fluent analysis, the iterations gives the Cl values varying from -5.23e-2 to -5.53e-3as shown in table1. This shows the variation of Cl at 0^0 angle of attack when the blended winglet is attached at 30^0 angle to the wing.

Table -1: CL Iteration Table for 30° at 0° angle of attack

S. No	Iterations	CL Values
1.	1	-5.23522e-02
2.	2	-1.08329e-02
3.	3	-8.73553e-03
4.	4	-4.84802e-03
5.	5	-4.69027e-03
|	|	|
93.	93	-5.53509e-03
94.	94	-5.53441e-03
95.	95	-5.53488e-03
96.	96	-5.53421e-03
97.	97	-5.53470e-03

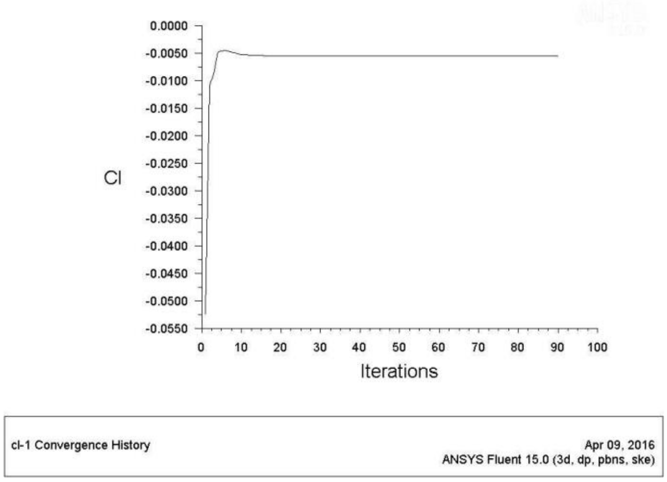

Fig 8: CL Convergence graph of 30° winglet at 0° angle of attack

4.1 Lift (KN) Generated at varies Angle of Attack:

The table2 below shows the lift generated at various angles of attack when the winglet is placed at 30 degrees or 90 degrees. By the observation of values in the table we can say that 90 degrees winglet can be used only in 4 and 8 degrees of angle of attack. Whereas the winglet kept at 30 degrees can be used only for 0 and 4 degrees of angle of attack.

Table 2: Comparison table for the lift generated at different angle of attack

Winglet angle	0 angle of attack	4 angle of attack	8 angle of attack
90 degree Winglet	317.35	135.09	440.10
30 degree winglet	442.68	183.66	162.14

4.2 Drag (KN) Generated at varies angle of attack:

The table below shows the drag generated at various angles of attack when the winglet is placed at 30 degrees or 90 degrees. By the observation of values in the table3 we can say that 90 degrees and 30 degrees winglets can be used for any angle of attack.

Table 3: Comparison table for the drag generated at different angle of attack

Winglet angle	0 angle of attack	4 angle of attack	8 angle of attack
90 degree Winglet	111.15	514.80	550.62
30 degree winglet	196.95	308.77	469.20

5. CONCLUSION

The induced drag created at the wingtips can be reduced placing a winglet at the wingtips which leads to the increase in L/D ratio, fuel efficiency. The wing without winglet experiences high amount of induced drag due to the boundary layer separation which leads to vortices created at tip so by attaching the winglet the boundary layer separation is delayed which causes less amount of vortices. The winglets can be placed at different angles with respect to wing to increase performance. By observing the results obtained we can conclude that by placing winglets at 90° to the wing we can achieve better performance of the wing instead of placing at different angles.

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