DESIGN AND ANALYSIS OF AERODYNAMIC PERFORMANCE OF A WINGLET AT VARIOUS CANT ANGLES

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ABSTRACT

In order to analyse the aerodynamic performance of aircraft winglet, a winglet is designed in Solid works and analysed in Ansys software. The tip vortex is the circulated flow of air near the wing tip which trails behind the wing when aircraft moves forward. The drag caused by the wing tip vortices aid the total drag in contributes significantly and causes many problems to aircraft like low stability, decreased lift, increased drag etc. the winglets reduce the drag due to tip vortices and increase the stability of wing during flight by reducing the total drag. Aircraft wings with winglet at various cant angles and without winglet is designed and analysed. The project shows the effect of winglets in the aerodynamic performance of wing and performance of aircraft wing at various cant angles of winglet. The results are compared and plotted. The winglet reduces the drag and increase the aerodynamic performance of aircraft wing and deceases the extra thrust needed to overcome this drag force due to tip vortices. Hence, also increase the fuel efficiency and stability of the aircraft.

Key words: Winglet, Tip Vortices, Induced Drag, Comparison.

1. INTRODUCTION

The lift force in wing is generated because of the pressure difference between the upper and lower surfaces of aircraft wing. This change in pressure at the tip of wing creates a circulated motion of air near the tip of wing as the wing moves forward which have a certain strength, which trails behind the wing and is called tip vortices. The tip vortices induce downward component of air velocity called downwash and it affects direction of the relative air velocity, which in change the direction of relative air velocity. Because of this change of direction of relative wind, the lift vector tilts in a particular angle called induced angle. This tilting of lift vector creates a horizontal component of lift force called induced drag which in turn aids the total drag. When the pressure difference at the tip of the wing is stronger, stronger the tip vortex formed and causes stronger downwash and stronger induced drag. So, it is important to reduce the strength of tip vortex.

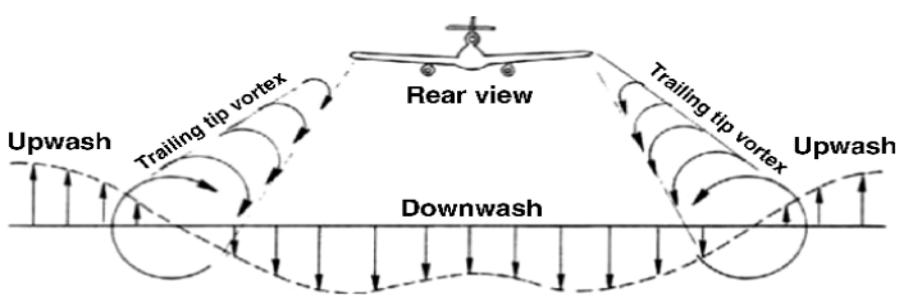

Figure 1 Tip vortex

The winglet is attached to the normal wing in order to reduce the induced drag and strength of tip vortex. Due to winglet, the change in pressure at the tip of the wing reduced and creates a forward thrust to reduce the strength of the tip vortex.

There are different types of winglets are used in aircrafts like blended winglet which function as the same principle as above. These winglets are very useful during long cruising flight conditions.

2. MODELLING

The designing of wing with winglet and without winglet are designed in Solid works software. The wing of Boeing 767 aircraft is chosen as the reference for designing the wing. The dimensions of the scale down for easiness of solution calculation. The aircraft wing is designed with winglet 0, 20, 45, and 60 degrees of cant angles and certain factors for all wing models made constant for the purpose of comparison. The wing with winglet of zero-degree cant angle is exactly like a wing without winglet.

Wing area, root chord, tip chord, winglet tip chord, taper ratio of the wing and taper ratio of the winglet are the factors that are made constant for all models. It is not able to use exact aerofoil of Boeing 767 which is in service today. So, NACA 2213 aerofoil is used for the designing of both wing and winglet. The dimension of the scaled model of wing and winglet is as shown below.

Span of the wing	0.5 m
Length of winglet	0.099 m
Root cord	0.18 m
Tip chord	0.024 m
Taper ratio of wing	0.27
Taper ratio of winglet	0.5

Winglet at 0 degree or without winglet:

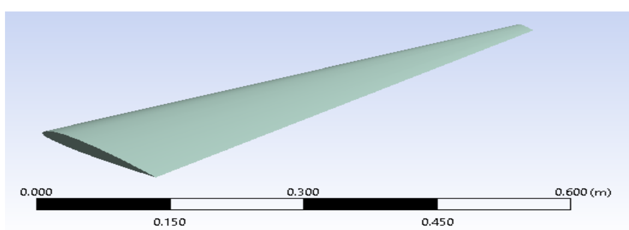

Figure 2 Winglet at 0 degrees

Winglet at 20 degrees:

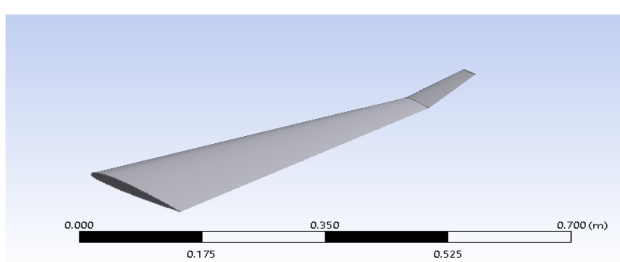

Figure 3 Winglet at 20 degrees

Winglet at 45 degrees:

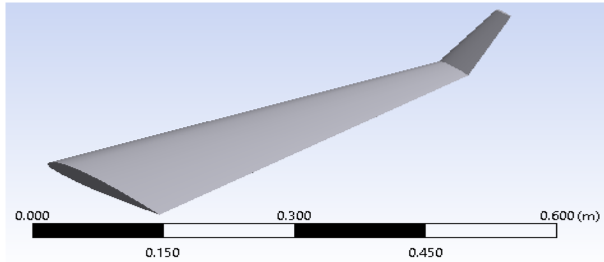

Figure 4 Winglet at 45 degrees

Winglet at 60 degrees:

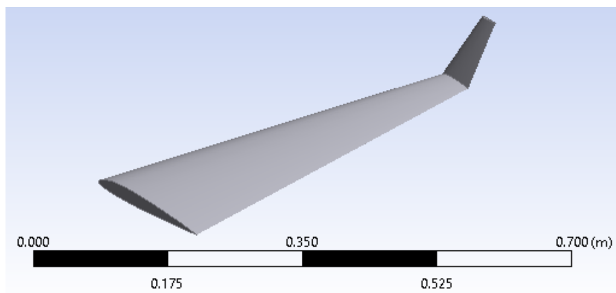

Figure 5 Winglet at 60 degrees

3. ANALYSIS

The aircraft wing with winglet and without winglet are analysed in Ansys fluent software and the analysis setup are the following for the calculation of aerodynamic forces. The meshing of the model is generated in appropriate size as shown in the figure and unstructured tetra elements are used for meshing, also suitable inflation is given. The designed wing models are analysed at a velocity of 100 m/s and 160 m/s, to find the performance at higher velocities. The k-eplision flow model is used for analysis with non-equilibrium wall functions. The pressure contour plots for the wings with winglet at various cant angle are observed and the aerodynamic force generated on the wing is found out and compared.

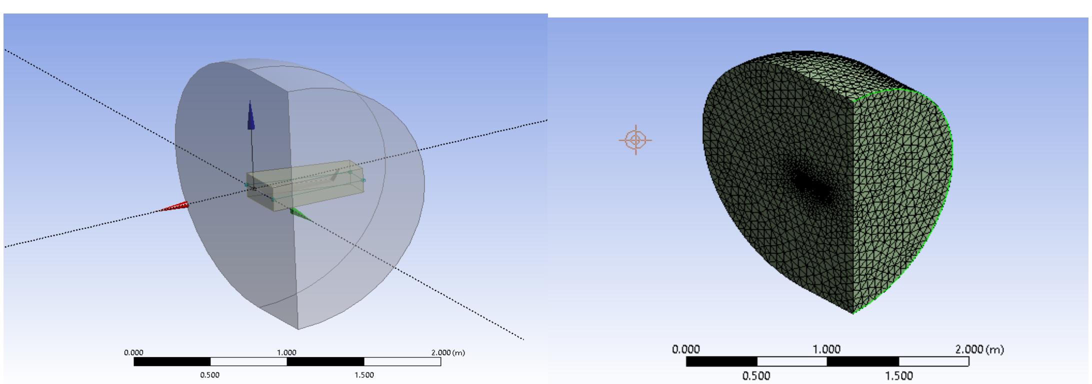

Figure 6 Control volume and meshing

4. RESULTS

The pressure contours of the different wing models obtained from Ansys software results are shown below.

Winglet at 0 degree:

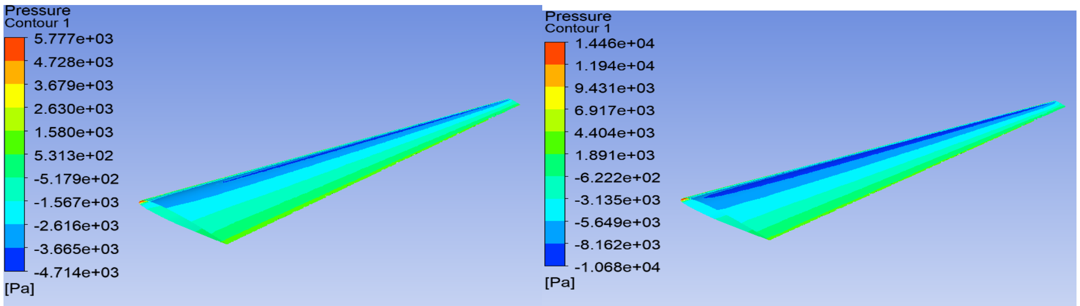

Figure 7 Pressure contour of wing at 0 degrees cant angle at 100 and 160 m/s

Winglet at 20 degrees:

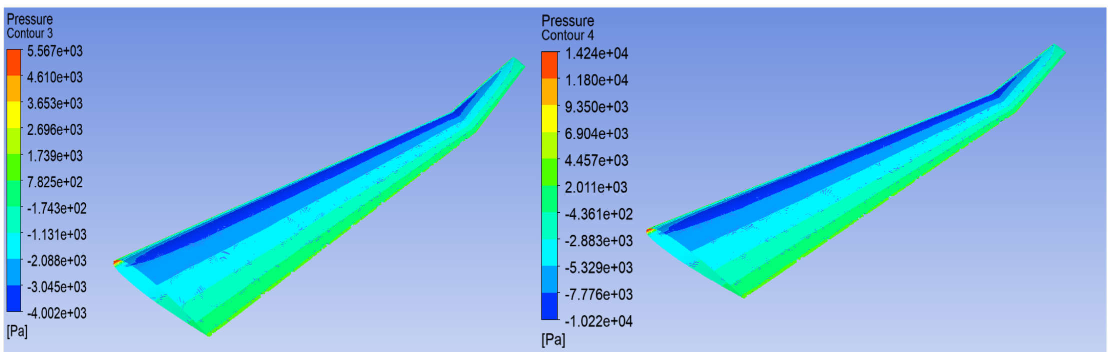

Figure 8 Pressure contour of wing at 20 degrees cant angle at 100 and 160 m/s

Winglet at 45 degrees:

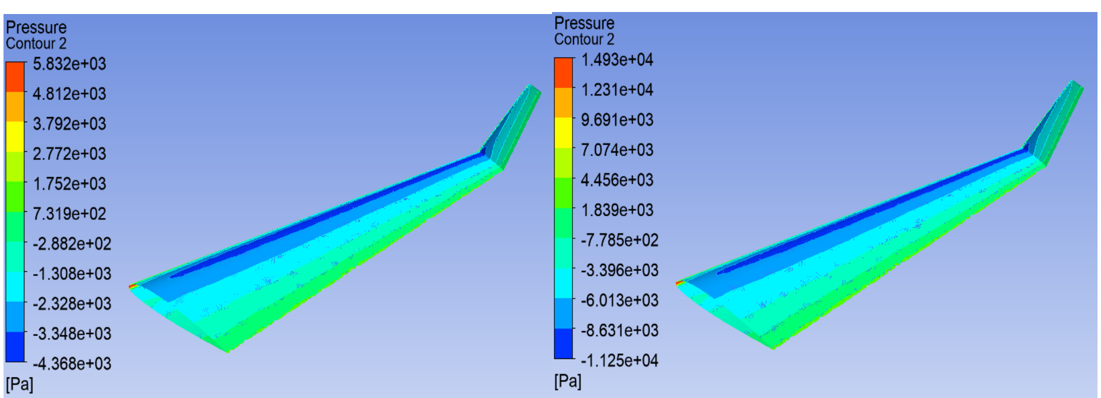

Figure 9 Pressure contour of wing at 45 degrees cant angle at 100 and 160 m/s

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Winglet at 60 degrees:

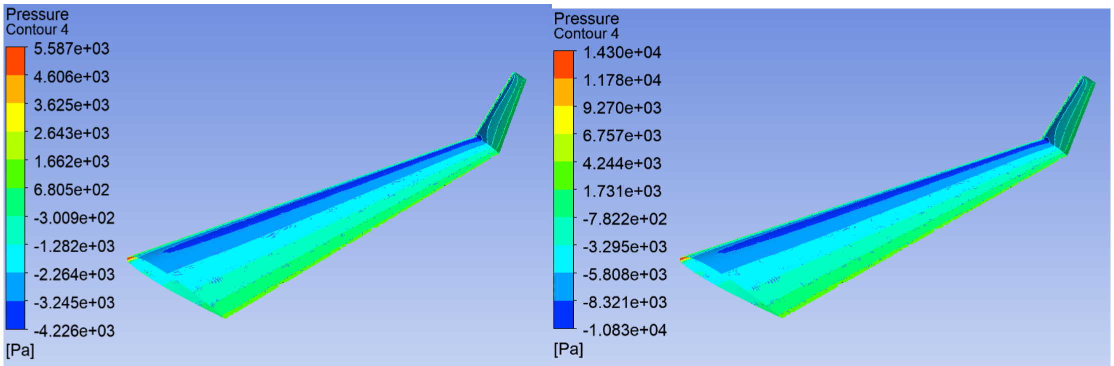

Figure 10 Pressure contour of wing at 60 degrees cant angle at 100 and 160 m/s

The lift-drag forces acting on wing models and their coefficients are tabularised to compare the performance of the wings with different cant angles. The L/D ratio of the wing models are calculated and plotted in the graph to analyse the performance of wing at various cant angles of winglet.

Cant Angle (degrees)	Velocity (m/s)	CL	CD	L (N)	D (N)	L/D
0	100	0.0088	0.0011	54.28	6.93	7.79
	160	0.0085	0.0011	133.3	17.68	7.53
20	100	0.0082	0.0011	50.62	7.18	6.96
	160	0.0146	0.0019	129.39	17.57	7.36
45	100	0.0084	0.00056	51.66	6.1	8.46
	160	0.0086	0.00091	134.99	14.38	9.38
60	100	0.008	0.0011	49.5	7.16	6.9
	160	0.008	0.0011	126.67	17.52	7.23

Table 1 Performance of wing at various cant angles of winglet

On observing the graph plotted, the aerodynamic performance of the wing increased in the presence of winglet. At particular cant angle of winglet, the aircraft wing gives maximum aerodynamic performance.

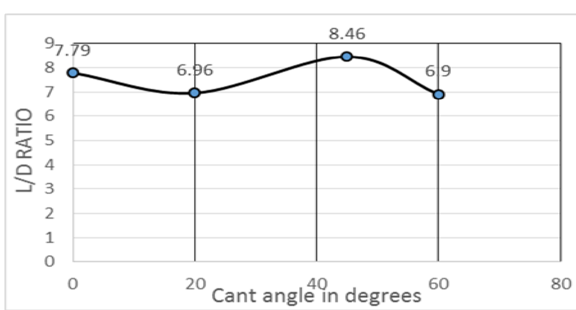

Figure 11 L/D ratio curve at 100 m/s

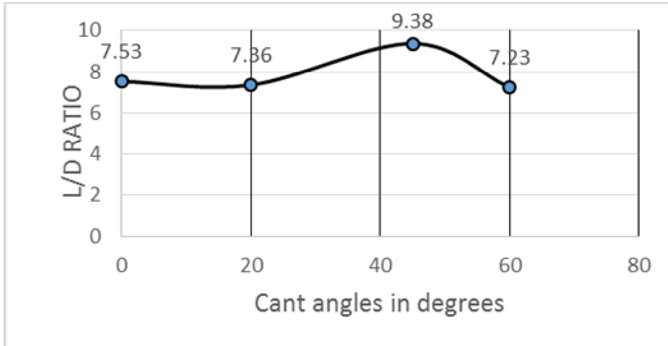

Figure 12 L/D ratio curve at 160 m/s

5. CONCLUSION

A winglet increases the aerodynamic performance of the wing by reducing the drag due to vortices. The L/D ratio of wing with winglet is higher than that of wing without winglet. Stronger tip vortices are formed at higher cruise velocities and the winglets are very effective in reducing the drag at higher velocities. From the result it can be observed that, the drag is reduced by 18.6 percentage when the winglet is attached at 45 degrees compared to wing without winglet at 160 m/s cruise velocity. Also, the performance of the wing varies with the cant angle of winglet. For the above wing structure, about 45 degrees of cant angle is best for reduced drag formation. Further experiments in wind tunnel experiment are needed to study more about winglets.

REFERENCE

[1] M Dinesh, Prem Kumar P S, J S Rao, Dr. C Senthil Kumar, “Performance Analysis of Winglets using CFD Simulation”, Altair Technology Conference, 2013.

[2] A. Rajesh, Praveen A S, and Dr. M S Ganesha Prasad, “Design and Analysis of UCAV Wing with a without winglet by varying the Cant Angle”, IJERT, vol. 4, issue 5, 2015.

[3] D. P. Raymer, "Aircraft design: a conceptual approach" American Institute of Aeronautics and Astronautics", 1999, USA.

[4] R.T. Whitcomb, "A Design Approach and Selected Wing-Tunnel Result at High Subsonic Speed for Wing-Tip Mounted Winglets," NASA TN D-8260, 1976, USA.

[5] R. T. Jones and T. A. Lasinski, "Effect of Winglets on the Induced Drag of Ideal Wing Shapes," NASA TM-81230, 1980, USA.

[6] Dr. PARCHURE Narendra P. and Dr. SOMAN Pallavi Y. Disaster Following Natural Events-Prevention and Management of Disaster. International Journal of Management, 7(1), 2016.

[7] Kolli Ramesh and Mr. A. Ashok Kumar. Design of 8-Bit Current Steering Digital To Analog Converter Using Full Swing GDI Logic, International Journal of Electronics and Communication Engineering & Technology, 6(9), 2015.