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Experimental Investigation Of Effect On Coefficient Of Lift Using Fixed To Flexible Winglets

Ramakrishnan B Durai Karthikeyan K Faizur Rahman Nasir M Achyuth Yadav V Syam Narayanan S

Abstract

Wingtip devices are used to improve the efficiency of the fixed wing aircraft by reducing the total drag which may lead to reduction in coefficient of lift. The winglets acts partially like an end plates to an aircraft wing. This device reduces the pressure nullification at the wingtips to a large extent and diminishes the adverse effect of the wingtip vortices. Thereby it results in the reduction of induced drag.Aerodynamic efficiency is an important factor in commercial aircrafts where in induced drag plays a major role. Strength of wingtip vortices is inversely proportional to wingspan and speed of the plane.. So aircraft with large wingspan and high speed will have high wingtip vortices. Thus the vortices will be maximum during takeoff, climb and landing. Changing the design of the lift producing devices will make changes in the strength of the aircraft. Winglets are extensions at the tip of the wing which reduces the vortex formation. Many types of winglets are available to serve different purposesThe primary focus of this paper is to investigate the effect on coefficient of lift using fixed to flexible winglets. A model was fabricated and tested in low speed wind tunnel for different inlet conditions and angle of attack, the coefficient lift for each winglet is compared.

Key words-coefficient of lift-fixed winglet-flexible winglet-wing tip vortices

I. INTRODUCTION

Wing is a lift producing part of an aircraft. Lift is a force acting upwards on due to change in the pressure above and below the wing. Pressure below the wing will be higher than pressure above the wing. So at the tip of the wing, air will tend to move towards the top. The resultant of these air movement forms the vortex behind the wingtip. Thus an induced vortex(drag) is formed. The downwash by trailing vortex system adds to the downwash produced by the bound vortex system, thereby increasing the strength of the wing tip vortices formed. Effect of this vortex formation plays a major role in total drag of the aircraft. Reducing the vortex formation will decrease the operating cost of an aircraft.

These are used as additional lift producing devices in olden aircrafts. Later its effect on decreasing the induced drag opened a broad way for the winglet design. Vortex diffuser vanes, wingtip sails are also used to reduce the vortex formation. But winglet provides a maximum efficiency.

Reducing the strength of the wing tip vortices at a given angle of attack will reduce the downwash on the wing. If 10% of this drag is reduced it is estimated that 13 million gallons of fuel for a low speed commercial aircraft can be save over its life time (Thomas 1985). Apart from increasing the efficiency the fuel consumption is also reduced which in turn reduces the global warming caused due to fuel consumption. It is estimated that world’s commercial aircrafts create more than 600 million tons of carbon dioxide per year(Barnett 2006). The strength of the wing tip vortices crated is directly proportional to weight of the aircraft; hence larger jet aircrafts create large wing tip vortices of maximum strength during takeoff, climb and landing phases. These vortices prevail for several minutes along with the wind, A small plane proceeding by the same runway of the large aircraft have the risk of uncontrollable and sudden variations in altitude. At worst cases the circular nature of wing tip vortices can flip the small plane upside down.

THEORY

Wing tip vortices are the circular patterns of air formed as the aircraft generates lift. Mostly this type of drag is also called as lift induced vortices as lift is the main cause for this circular formation. The theory behind the formation of wing tip vortices is that the difference between in pressure between the upper and lower part of the wing make the is flow from bottom to top as air always flows from high pressure region to low pressure region in order to nullify the pressure difference created,. The oncoming flow stream as the aircraft proceeds forward creates a bound vortex that flows towards the trailing edge of the wing. The bound vortex combines with the tip vortex generated and strengths the vortex formed thus forming a wing tip vortex circulating at the tip. This flow is strong at the tip and decreases to zero as it goes to the mid span.

The tip vortices formed is directly proportional to the weight of the aircraft which means for heavier aircrafts the tip vortices formed is very large and decreases gradually as the weight decreases.

The research in winglets started since 1976, these are the physical barriers created at the end of the wing tip so as weaken the tip vortices formed.

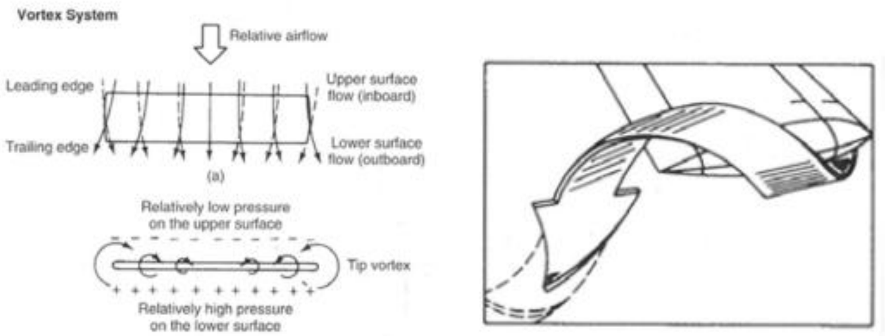

Figure 1. Pressure equalization on the wing tip and vortices (Bertin & Smith, 1998)

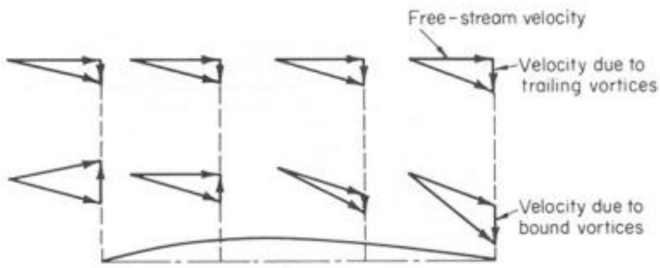

Figure 2. Downwash due to bound and trailing vortices (Hoerner, 1965)

The property of winglet is to reduce the wingtip vortices formed there by increasing the lift and efficiency. The up wash/downwash effect makes the air to flow from bottom to top of the aircraft at the tip, the winglets placed at the tip acts as physical barrier so that when the air tries to move to up it has to cover the area of the winglet so as to reach the upper surface so as to nullify the pressure difference.as the air travels through the area of the winglets it gets weakened and the tip vortices created gets reduced considerably.

The research in winglet was initially done and introduce by whitcomb in 1976. According whitcomb the winglets could reduce wing tip vortices created by 20 percent and it results in 9 percent increase in lift to drag performance of the aircraft at mach 0.78.winglets impose less weight and drag than increasing the wing span so as to reduce the wing tip vortices.

EXPERIMENTATION

FABRICATION

The wing used in Boeing 737 was selected as the reference aerofoil so as to test the vortex formation with and without winglets.NACA 66_2-215 was selected and designed using catia designing software. The internal structure of the wing involving the ribs and spars was created using teak wood and iron rods so as to connect the designed aerofoil. The outer shell of the wing was covered using aluminum al0oy sheets.

The use of teak wood gives better rigidity to the aerofoil when cutting under mini saw and it possess smooth surface giving smooth surface finish to the aerofoil. The aluminum alloy sheets uses gives smooth bending without much dents while ending for wing cover and for winglets fabrication. Initially the wing without wing let is fabricated, thedimensions of the wing is given below. NACA 66_2-215 airfoil is selected. Wing is fabricated for wing span of 330 mm with root chord of 165 mm and tip chord of 40 mm.

The winglets for the selected wingspan are created using catia designingsoftware. Totally five winglets were selected four fixed winglets and one flexible winglet.

Figure 3 Fabricated wing structure without winglet (Flat)

Phase angle is the angle made by tip of the winglet and normal component of free stream velocity. Three winglet were designed with the phase angle of Φ=0, 50, 25, and the forth one a multiple winglet having plottedwinglets of angles Φ=0, 50, 25.

Figure 4 Experimental arrangement for testing with winglet of phase angle 25 deg.

FIBER WINGLET CONCEPT

Fiber winglet holds the concept of flexible winglet. This winglet was fabricated with natural kenaf fibers attached to aluminum alloy ends.

The concept to use fiber in the wing let design is that a winglet that is flexible like feathers so that it bends at different angle of attack and at different velocities.

The main advantage of this winglet is that it and bends according to the airflow produced enough to reduce the generated wing tip vortices. This possesses the capacity toproduce greater bend at maximum velocity and minimum bend at lower velocities.

Figure 5- Flexible winglet attached wing structure

PREASURE TUBES

The pressure tubes used to connect the ports on the wing are PU tubes, (poly urethane tubes).The PU tubes give better flexibility and do not interrupt the flow due to bending. Totally 22 ports were drilled on the wing.10 ports at the 80 percent of the span and 12 ports at the 50 percent of the span.Each port is connected to the PU tubes so as to be connected with the manometer for pressure readings.

MOUNT

The fabricated wing is mounted to a rectangular board made of wood holding a plastic disk at the center so as to fix the wing to the mount so that it can be mounted inside the wind tunnel. Steel tube of 16mm diameter is used to hold the wing to the mount of the wind tunnel.

TESTING

WIND TUNNEL CALIBRAION

For testing velocities=10, 15, 20, 25m/s respectively are selected so as to test the fabricatedwing. The wind tunnel is calibrated for different Rpms and the corresponding rpm for the selectedvelocities are noted. Rpm=300, 440, 575, 720.

MODEL TESTING

The model was mounted to the wooden board. Initially the wing without winglet is tested for the selected velocities; the pressure head for each velocity are noted.

Then the wing is cut at 80 percent and the winglet is attached. Tests are done for three different angle of attacks ϴ=0, 5, 10, and at four different velocities. Then the winglet is removed and the other is attached for next set of testing, so totally 36tests were made including the wing without winglet. A multi tube manometer is used to measure the pressure readings noted.

INFERENCE

The values obtained from the pressure heads are used to plot the C_p curve, from which C_l values are calculated. In the fig below, Flatindicates the wing without winglet. The lift coefficient vs. velocity graphs are listed below

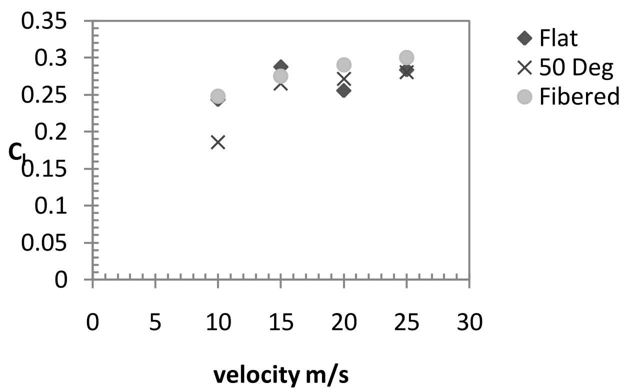

Figure 6- Coefficient of lift vs Velocity for angle of attack 0 degree.

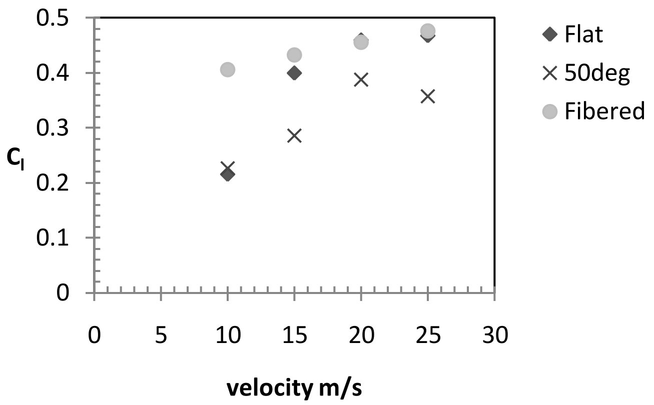

Figure 7- Coefficient of lift vs Velocity for angle of attack 5 degree.

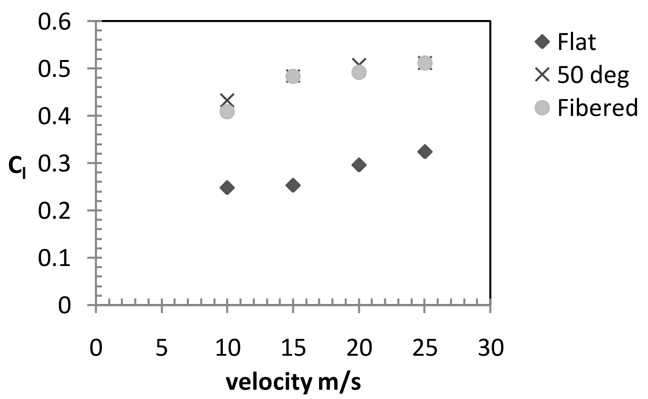

Figure 8- Coefficient of lift vs Velocity for angle of attack 10 degree.

CONCLUSION

From the Experimental results obtained the coefficient of lift values of wingletsare compared. From all the three winglets tested, Winglet with fiber projections provides high lift coefficient. At angle of attack 5 and velocity 25 m/s, C_l obtained for fibered winglet was high compared to the other winglets.

So thus we conclude that fiber winglet design leads to decrease in vortex formation thus maintaining lift to larger extent.

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