Design and Performance Analysis of Spiroid Winglet with Normal Wing

Dr G. Manikandan¹, V.Rajashree² & S. Merryisha Sweety Gracia³
¹Head of Department, Dept. of Aeronautical Engg, SNS College of Technology
²Assistant Professor , Dept. of Aeronautical Engg, SNS College of Technology
³UG Scholar, Dept. of Aeronautical Engg, SNS College of Technology

Abstract: In Aeronautical Engineering, the concept of flight plays out the most important role. The aerodynamic and the mechanical drag formation has playing out the demanding role for the total drag formation. The drag reduction constitute a challenge gradually uplifts the total Aircraft Performance. The cut-off drag performance has manly contributed by the Induced Drag for about 40% during Cruising and 80-90% during takeoff and landing. The main role of winglets is to reduce the induced drag formation. Winglets are small structure which plays a vital role to reduce the induced drag in aircraft. In this project, literature survey is made on various types of winglets and finalized to design and analyze the spiroid winglet. The two main airfoils are being considered i) NACA 0012 ii) NACA 2412. Our project is to overcome the difficulty faced by other winglet models and also mainly concerned on decreasing the induced drag and also concentrate on parasite drag. Our project is carried out in Boeing 777 wing without extension by placing a winglet at the tip. During every cruising condition of an aircraft the vortices formation at the wing tip reduces the efficiency and contributes the maximum percentage of the total drag. Reducing the process time in design is one of the important criteria for any field and hence automation with help of CREO is very significant in reducing time. CREO software is dispatched to develop the template of “Spiroid Winglets.

Then the template of the model (from the CREO) is imported to the CFD software’s like Fluent & ANSYS 14.5 for analysis and execution process. From the results, the “Spiroid Winglets” is efficient than the blended winglets and conventional wing is literally proven.

Keywords: winglet, induced drag, spiroid winglet, ANSYS 14.5, FLUENT & CREO.

I. Introduction

A wing in an aircraft produces aerodynamic forces facilitating movement through liquids. The top of the wing produce lower air pressure which generates smaller downward force than the bottom of the wing produce higher air pressure which generates upward force. Hence, lift is generated due to the upward force. The force of lift completely depends on the interaction of the air molecule with airplane wings. The lift force is mainly produced due to its stream line body and due to the generated speed and angle of attack. Lift-to-drag ratio express the wing aerodynamic quality. The lift can be calculated from different velocities, pressure differences. The design and analysis of the wings of aircraft is one of the principal applications in the science of aerodynamics. Cross sectional view of an aircraft wing is shown in Fig.1.

Winglet is a device used to describe an additional lifting surface on the aircraft. Winglet devices are usually intended to improve the efficiency in fixed-wing aircraft. The strength of the wingtip vortices has been reduced, which is hazard to the aircraft because of the envelop around the wing tip. It also reduces the required takeoff distance. Types of winglets are shown in fig.1.2.Winglets and wing fences increases the efficiency by reducing vortex interference with laminar airflow near the tips of the wing. It also reduces wingtip vortices and the difference between the pressure on the upper surface of an airplane's wing and that on the lower surface. It produces good performance for reducing drag. This
reduction could translate into marginally higher cruise speed. The concept of winglet has been adopted by Frederick W. Lanchester, an English engineer as a method to control wingtip vortices.

**II. Base Design**

In order to compare the benefits of the spiroid winglet, Boeing 777 wing has been considered without wingtips. A normal complete wing has been compared with the spiroid winglet, where the specification for both the wing remains the same. The winglet configuration changes. Henceforth the designing configuration is very important to resolve the drawbacks of normal wing. The design is done by CREO and the analysis is carries out by ANSYS 14.5.

**a. Design Parameters**

The complete design of normal wing is shown in Fig 3 and the design of spiroid winglet is shown in Fig 4. The design specification of the normal wing and the spiroid winglet is tabulated in Table 1 and Table 2.

**III. Governing Equations**

**A. Induced Drag Coefficient**

Spillage is being created around the wing tips due to the pressure difference around the wing. Downwash causes a local induced angle of attack with additional induced drag on the finite wing.

\[
\text{Aspect Ratio} = AR
\]

\[
AR = \frac{s^2}{A_c}
\]

\[
\text{C}_{d_i} = \frac{c_l^2}{\pi ARe}
\]

\[
C_L = \frac{L}{1/2 p_0 V_e^2}
\]

- Efficiency factor = \(e\)
- For an ellipse \(e = 1.0\)
- In general \(e < 1.0\)
There is a mathematical equation that quantifies the effects of induced drag. For a wing, the total drag coefficient, $C_d$, is equal to the base drag coefficient at zero lift $C_{d0}$ in addition to the induced drag coefficient $C_{di}$.

$$C_d = C_{d0} + C_{di}$$

$$C_{d0} = \frac{L^2}{1/4\nu^2 \pi e A \rho^2}$$

### B. WING LIFT EQUATION

- $L = \frac{1}{2} C_L \rho V^2 A$
- $C_L = \frac{2L}{\rho V^2 A}$
- $\rho = \frac{C_L V^2 A}{L^2}$
- $V = \sqrt{\frac{2L}{C_L \rho A}}$

Where,

- $A$ : lift surface area
- $AR$ : Aspect ratio
- $C_{d0}$ : induced drag coefficient
- $C_L$ : coefficient of lift
- $D_i$ : induced drag
- $L$ : lift force
- $V$ : Take off velocity
- $c$ : chord length
- $e$ : Ostwald’s efficiency factor
- $t$ : maximum thickness
- $\nu$ : true air speed
- $v_e$ : equivalent airspeed
- $\rho$ : air density (sea level)
- $\rho_0$ : air density (altitude)

### IV. Meshing

#### A. Mesh of Normal Wing and Spiroid Winglet

The meshed view of the normal and spiroid winglet models are showed in the Fig 5 & Fig 6.

![Figure 6 Meshed view of normal wing](image1)

![Figure 7 Meshed view of spiroid winglet](image2)

### V. Boundary Conditions

#### A. The general boundary condition for both the normal wing and Spiroid winglets are:

- The flow of air is considered to be incompressible and subsonic.
- The free stream airflow has been maintained between 133 m/s to 150 m/s.
- The density of air is 1.225 kg/m$^3$.
- The operating pressure is 19351.45 pa.
- Atmospheric Pressure is 101325 Pa.
- Atmospheric Pressure at 13 km is 16500 pa.
- Wall: Stationary Wall
- Turbulence: K-E Model
- Steady State flow is assumed
- Air is considered as Working fluid

#### B. Inlet Condition

- Static pressure – 16500pa.
- Static temperature – 216.2k
- Mach number – 0.5
- Velocity = 160 m/s
  
  
  $a = \sqrt{\gamma R t}$

  $\gamma = 1.4$

  $R = 287$

  $t = 300$
C. Isentropic Equation
To determine the pressure and temperature at 13.13 km isentropic equation is used.

\[ P = \left(1 + \frac{\gamma - 1}{2} \cdot M^2\right)^{\frac{\gamma}{\gamma - 1}} \]

Where,
- \( P \) → unknown pressure for known altitude
- \( P_t \) → known pressure,
- \( \gamma \) → Ratio of Specific heat (1.3)
- \( M \) → known Mach number

VI. Analysis
Analyzing comparison of normal wing and spiroid winglet

A. Normal wing at velocity 133m/s with 0° angle of attack.

B. Spiroid winglet at velocity 133m/s with 0° angle of attack.

C. Normal wing at velocity 150m/s with 0° angle of attack

D. Spiroid wing at velocity 150m/s with 0° angle of attack

E. Normal wing at velocity 133m/s with 4° angle of attack
F. Spiroid wing at velocity 133m/s with 4° angle of attack

G. Normal wing at velocity 150m/s with 4° angle of attack

H. Spiroid wing at velocity 150m/s with 4° angle of attack

VII. Results and Graphs

A. Comparison of $c_L$ and $c_D$ of Normal wing and Spiroid wing with angle of attack

Figure 24 AOA, $c_L$ of normal and spiroid wing

Figure 25 AOA, $c_D$ of Normal and Spiroid wing
### VIII. Conclusion

The parasite drag and induced drag plays a vital role in the formation of total drag which decreases the efficiency of aircraft. Various shapes of winglets are being used by Boeing and Airbus. Many literatures have been overviewed and each and every type of winglets performance has been studied and selected a spiroid winglet concept in order to increase the aerodynamic performance. The spiroid winglet has liberal optimization in vortices suppression. In the project, symmetrical spiroid winglet is used in Boeing 777 to enhance the further improvement in lift characteristics and reduce the total drag formation.

The comparative study on Boeing 777 with spiroid winglet and without winglet is studied in detail with different angle of attack using software analysis, ANSYS 14.5. From the analysis it is clearly seen that the performance of the spiroid winglet is better than the normal wing when compared to the $C_L$ and $C_D$ values at 4° angle of attack.

### IX References


