DESIGN AND ANALYSIS OF SPIROID WINGLET FOR DRAG REDUCTION

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Abstract—All Aeronautical and Aerospace developments of late have been primarily focused on improving the range and endurance of the Aviation vehicles. Tremendous amount of focus is given for ensuring the safety of flight and Airworthiness of the aircraft. The major demand associated with the aviation industry is the reduction in the drag and increase in the lift. With the increase in the usage of aircraft all over the world, there has been the great problem of the management of aircraft in this sector. Air traffic control has great workloads and issues handling these numerous aircraft at the major airports due to the high flow efficiency and the spacing required after successive takeoffs and landings. This can be reduced if the wingtip trailing vortex energy are recovered. This proposed system aims to reduce the induced drag caused due to the vortex trailing behind the wingtips by the recovery of the wingtip vortex energy by the use of spiroid winglet. The present study deals with the investigation of effects of spiroid winglets design on the aerodynamic performance of the aircraft. The study consists of designing of the spiroid model and carrying out the computational fluid dynamic simulations to simulate the spiroid winglet design having significant aerodynamic performance.

Keywords—Spiroid winglet, Coefficient of drag, Coefficient of lift, Drag reduction, Lift to drag ratio

I. INTRODUCTION

Wingtip devices are usually intended to improve the efficiency of fixed-wing aircraft. There are several types of wingtip devices, and although the 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 for following aircraft. Such devices increase the effective aspect ratio of a wing without materially increasing the wingspan. 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. Finite span wings generate lift due to the pressure imbalance between the bottom surface (high pressure) and the top surface (low pressure). However, as a byproduct of this pressure differential, cross flow components of the velocity are generated. The higher pressure air under the wing flows around the wingtips and tries to displace the lower pressure air on the top of the wing.

These structures are referred to as wingtip vortices and very high velocities and low pressure exist at their cores. These vortices induce a downward flow, known as the downwash and denoted by w. This downwash has the effect of tilting the free-stream velocity to produce a local relative wind, which reduces the angle of attack (α) that each wing section effectively sees; moreover, it creates a component of drag, the lift-induced drag.

The term "winglet" was previously used to describe an additional lifting surface on an aircraft. Another potential benefit of winglets is that they reduce the strength of wingtip vortices, which trail behind the plane and pose a hazard to other aircraft. Minimum spacing requirements between aircraft operations at airports is largely dictated by these factors. Aircraft are classified by weight (e.g. "Light," "Heavy," etc.) because the vortex strength grows with the aircraft lift coefficient, and thus, the associated turbulence is greatest at low speed and high weight. The drag reduction permitted by winglets can also reduce the required takeoff
distance. 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.

By applying biomimetic abstraction of the principle behind a reducing lift-induced drag is by using wingtip devices. By applying biomimetic abstraction of the principle behind a bird’s wingtip feathers, we study spiroid wingtips, which look like an extended blended wingtip that bends upward by 360 degrees to form a large rigid ribbon.

Spiroid winglet forms a closed loop at the wingtip. This loop has variations of cross section at different locations causing variations in lifting capabilities of wing. These type of winglets have known to be very efficient as compared to other known winglets. Spiroid winglets or wingtips are functionally made to reduce vortices footprint made by wing. Gratzer has developed the wingtip configuration on the right is opposite to that of left hand side. This design incorporates airfoil cross section with specified thickness, camber and twist.

Joel E. Guerrero [3] discussed the study which included many benefits of spiroid winglets which incorporated reduction in lift-induced drag, increase in slope of 9.0% in co-efficient of lift versus AoA curve and lift-to-drag enhancement. This research also concluded that introduction of spiroid winglets in aircrafts has few shortcomings as well. This includes increase in parasitic drag and weight of the aircraft but these factors can be compromised because benefits of introduction of spiroid winglets overcome its shortcomings.

V. K. Bada, K. Monika, A. Hussain, P. Chikoti[4] studied potential of spiroid and dual feather winglets are taken into consideration by using biomimetic abstraction principle of a bird's wingtip feathers, study of spiroid and dual feather winglets which look like extended blended winglets [5]. Both the types of winglets were tested on Boeing 737 wing for various AoA and this study concluded that spiroid winglets show better performance than dual feather winglets in terms of stalling angle, L/D ratio etc.

II. RELATED WORK

Some works related to the proposed system are mentioned below:

S. Mostafa, S. Bose, A. Nair, M. A. Raheem, T. Majeed and A. Mohammed, Y. Kim [1] presented the detailed study of spiroid winglets that produced efficient aerodynamic performance results in terms of L/D and induced drag etc. In this paper heuristic approach was carried out to modify basic spiroid design by changing its semi-circular/ovular shape to rectangular & parallel-piped and then introducing sweep angle to it. In this paper various simulations were carried out to check for the aerodynamic performance of each design and research was concluded by establishing the fact that FWD spiroid gave better results when compared to other types of winglets. This study also concluded that spiroid winglets are superior when compared to other two wingtip configurations in terms of vortex suppression and drag reduction.

L. B. Gratzer [2] filed first US patent on spiroid winglets was published by Louis et al. by the name of 'Spiroid-Tipped Wing'. It incorporated the very first spiroid wingtip design which was intended to be used for the minimization of lift induced drag and to alleviate noise effects associated with vortices that trail behind lifting objects. This basic design comprised a closed loop which initiates from wingtip at appropriate sweep and included angles to form a continuous and closed loop at the wingtip [8]. In this design it was established that the spiroid configuration should be such that for fixed wing aircraft the spiroid configuration on the right is opposite to that of left hand side. This design incorporates airfoil cross section with specified thickness, camber and twist.

III. OBJECTIVES

The objectives of this study are listed in detail as the followings:

The main objective is to reduce the drag by partial recovery of wingtip vortex energy.

Obtain the fundamental knowledge about spiroid winglet and its impact on aircraft aerodynamic performance.

Identify the optimum spiroid configuration in terms of shape, size, airfoil and sweep angle.

Analyze and improve the aerodynamic performance of the spiroid wing in terms of lift, drag, etc.

Compare the performance with a basic wing and a wing with spiroid winglet, in terms of pressure coefficients.

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IV. DESIGNED MODEL

In order to compare the benefits of the spiroid winglet, Boeing 737 wing has been considered without the 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 is changed. Henceforth the designing configuration is very important to resolve the drawbacks of normal wing.

The designing started with the selection of the airfoil and the wing for our project. The wing and winglet model are designed using Open VSP-3.16.2 and CATIA V5 Software using the following specifications:

Design specifications of wing are:-
- Wing Span:- 28.35 meters
- Tip chord length:- 32 meters
- Root chord length:- 1.6 meters
- Sweep Angle:- 25 degrees (Sweep backward)
- Airfoil :- NACA 2412

V. MESHING

The Computational Fluid Dynamic mesh has been done using OPEN VSP. After Meshing has been done, the following were the results obtained during the mesh. Here the water tight design is obtained. Triangular mesh has been carried out and the number of elements for different design model of wing and the wing with spiroid winglet is determined. The followings are the mesh parameters used for the meshing:

<table>
<thead>
<tr>
<th>Mesh parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXEDGE LENGTH</td>
<td>0.5</td>
</tr>
<tr>
<td>MINEDGE LENGTH</td>
<td>0.1</td>
</tr>
<tr>
<td>MAXGAP</td>
<td>0.005</td>
</tr>
<tr>
<td>NUM CIRCLE SEGMENTS</td>
<td>16</td>
</tr>
<tr>
<td>GROWTH RATIO</td>
<td>13</td>
</tr>
</tbody>
</table>

The number of the elements for the wing model is determined to be 22892 and the meshed view of the normal wing and the spiroid winglet are shown in the figure below.
VI. COMPUTATIONAL FLUID DYNAMIC SIMULATIONS

Computational fluid dynamics had been done by using VSPAERO. The grid structure has been developed to be focused around the models while being less condensed on the far flow field in order to manage the computational resources and minimize the time needed for carrying out the calculations. Computational fluid dynamics analysis for different values of angle of attack and different values of Mach number has been carried out. And coefficient of lift versus coefficient of drag has been plotted and shown below:

CL vs CD for the Wing at M=0.75

CL vs CD for the Wing with winglet1 at M=0.75

CL vs CD for the Wing with winglet2 at M=0.75

VII. RESULTS AND DISCUSSIONS

For the purpose of the comparison between overall coefficient of lift and coefficient of drag versus Angle of attack, table has been generated. Henceforth, the present study result has been validated by the comparison using the table established below.

As we can observe that as the lift increases the drag also increases. And the amount of lift decreased of wing with winglet with respect to the normal wing is due to the extra profile, surface due to the addition of the winglet which increases the profile drag.

Therefore, by looking down towards the graphs of Coefficient of lift versus Coefficient of drag for the wing model and the wing with the winglet model, it is obvious that the results of the wing with the spiroid winglet has overall better aerodynamic characteristics than the aerodynamic characteristics of wing model alone. The Coefficient of lift of the model is increased due to the addition the spiroid winglet and the Coefficient of drag has been reduced due to the addition the spiroid winglet.

<table>
<thead>
<tr>
<th>Angle of Attack</th>
<th>Wing</th>
<th>Spiroid Winglet 1</th>
<th>Spiroid Winglet 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient of lift ($C_L$)</td>
<td>Coefficient of total drag ($C_{D_{tot}}$)</td>
<td>Coefficient of lift ($C_L$)</td>
</tr>
<tr>
<td>1</td>
<td>0.26296</td>
<td>0.01135</td>
<td>0.24182</td>
</tr>
<tr>
<td>5.5</td>
<td>0.77877</td>
<td>0.03855</td>
<td>0.73536</td>
</tr>
<tr>
<td>10</td>
<td>1.41705</td>
<td>0.09254</td>
<td>1.34899</td>
</tr>
</tbody>
</table>

The reason behind the increment of lift and the decrement of the total drag is due to the decrement of the lift.
induced drag. 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 comparative study on Boeing 737 with spiroid winglet and without winglet is studied in detail using software open VSP aero analysis.

VIII. CONCLUSIONS
This paper presented the study of spiroid winglets and a detailed research analysis which was conducted in order to choose an optimum spiroid design that produced efficient aerodynamic performance results. The parasite drag and induced drag plays a vital role in the formation of total drag which decreases the efficiency of aircraft. The spiroid winglet has liberal optimization in vortices suppression. In this project, spiroid is used in boeing 737-100 original to enhance the further improvement in lift characteristics and reduce the total drag formation.

The comparative study on Boeing 737 with spiroid winglet and without winglet is studied in detail with different angle of attacks and different Mach numbers using VSPAERO. From the analysis it is clearly seen that the performance of the spiroid winglet is better than normal wing when compared to $C_l$ and $C_D$ values at different angle of attacks. In this for reducing inducing induced drag we used spiroid winglet. If, lift to drag ratio increases the drag will reduce here in the spiroid winglet the lift to drag ratio increases than wing without winglet so the spiroid winglet reduces the vortices.

IX. REFERENCES


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