SOUTH ASIAN JOURNAL OF ENGINEERING AND TECHNOLOGY

Full Length Article

Design and Analysis of Bird Inspired Multi Blended Winglets for Reducing Induced Drag

M. Kanimozhi[a], S. Prashanth[b]

[a] Student Department of Aeronautical Engineering, Excel Engineering College, Komarapalyam-637303, Namakkal, Tamilnadu, India

[b]Assistant Professor Department of Aeronautical Engineering, Excel Engineering College, Komarapalyam-637303, Namakkal, Tamilnadu, India

***Corresponding Author**
mkanimozhi55@gmail.com
(M.Kanimozhi)
Tel.: +91 9600428146

ABSTRACT: This paper represents the design and analysis of the bird inspired multi blended winglets for reducing the induced drag. In order to reduce the induced drag a device called winglet which is mounted at the tip of the wing. Different types of winglets have reduced the induced drag in different flights this represents the influences of the winglets in the reduction of induced drag is the most possible ways. The designed winglets provides an optimum reduction in the drag that created by the trailing vortices at the aircraft wing tip. It consists of analysing of winglet for several angles of attack to determine the coefficient of lift and drag. The values is then compared with the regular blended winglets and plot C_L and C_D for both wings. This winglet design will reduce the fuel consumption and make the aircraft more stable and also give the life of engine by reducing the drag. The winglet are modelled using CATIA VSR 20, the meshing is done by using TCEM CFD meshing and CFD analysis is done by using ANSYS fluent. The turbulence model used for analysis is Spalart-Allmaras. and solver is coupled solver using higher order differential terms. This software plays an important role in time to make the design, simulation and also the testing of model.

Keywords: Angle of attack, blended winglets, induced drag reduction, vortices.

1 Introduction

Winglet is a device, the aim of that is to improve the efficiency of the aircraft by reducing the induced drag. Winglet is the one of an additional lift producing surface of an aircraft. The use of winglet is that converted the wasted energy produced by the wingtip vortex to an useful thrust. In addition to find the better result in reducing the intensity of wake vortices. Winglets are also increase the efficiency by reducing the vortex interference with laminar airflow near the wing tip and this reduces the tip vortices and the twin vortices formed by the pressure difference between the upper and lower surface of the airplane wing. Airflow around the area of the wing tip behind them produce an vortex. This take the advantages of the drag reduction by throttling back to normal speed and also in the fuel saving. The airflow around the winglet device is very difficult and complicated and it have to be designed carefully and also tested. Winglet produce an good performance by reducing drag and that reduction could translate into marginally high cruise speed. A wing with high aspect ratio will provide longer range at a given speed. winglet provides the effect of increased aspect ratio without extending the wing span. Types of winglets,

- Regular
- Blended
- Raked
- Wingtip Fences
- Split Scimitar

2 Problem Description

The comparative study has been carried out the performance of the winglet while the angle of attack chances, the effectiveness is evaluated by observing the airflow around the surface of the winglet. The purpose of having a multi blended is to diffuse the induced drag tip vortices into small component thus reducing the total amount of induced drag formed due to lift. Each winglet will have a different cant angle with leading winglet having a higher cant angle than rear.

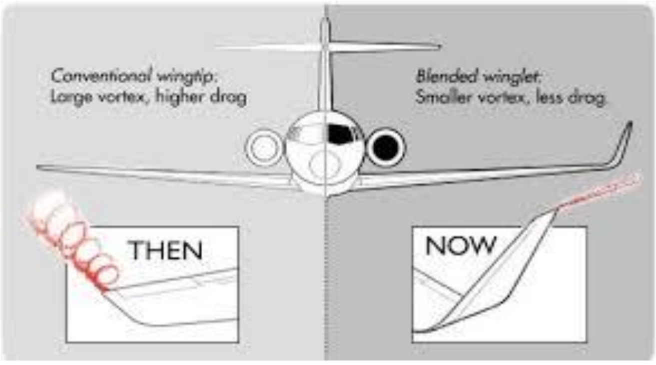


Fig - 1: Illustration of vortex development

3 METHOD OF SOLUTION

According to the equations below, a wing of infinite aspect ratio and constant airfoil section would produce no induced drag per unit of surface area. However in reality, there will be more drag when the angle of attack is high than when it is zero or slightly negative.

3.1 Calculation Of Induced Drag

For a planar wing with an elliptical lift distribution, induced drag is often calculated as follows. These equation make the induced drag depend on the square of the lift for a given aspect ratio and surface area of wing.

$D_i = \frac{1}{2}\rho V^2 S C_{Di}$

Where,

$C_D = \frac{1}{\Pi e AR} C_L{}^2$

Where,

AR - Aspect Ratio

C_L - Coefficient of Lift

C_D - Coefficient of Drag

V - Velocity

S - Wing Span

ρ - Air density

4 Process Methodology

4.1 Modelling

Design process of the winglet have been carried out using CATIA V5 R20 with the following design considerations.

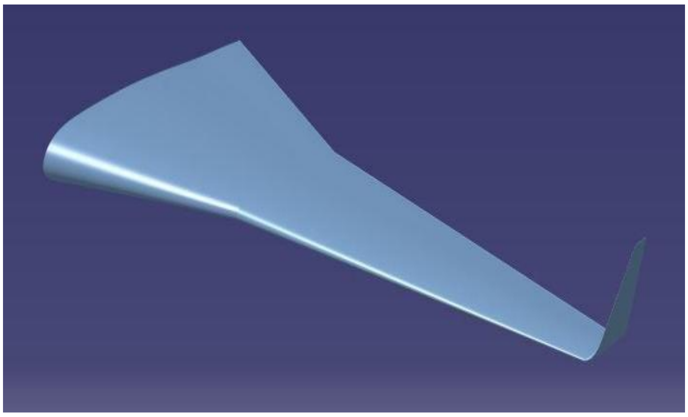


Fig - 2: Isometric view of the Conventional Blended Winglet

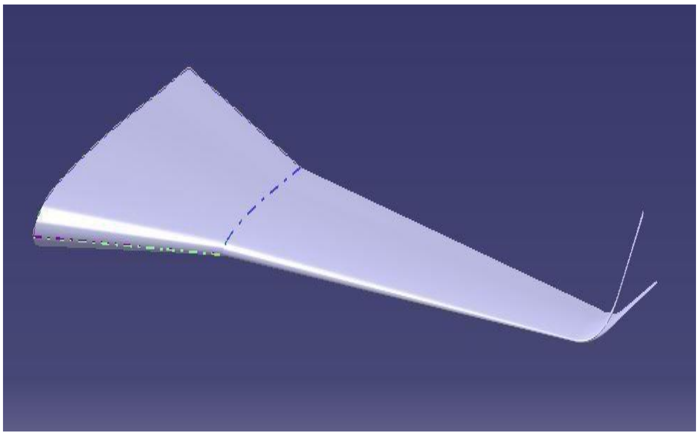


Fig - 3: Isometric view of Split Blended Winglet

4.2 Discretization

The winglet model is then discretized using ICEM integrated ANSYS Meshing tool. The domain is created in such a way the incoming flow should not disturb the wake region of the wing at any angle of attack using elliptical inlet face.

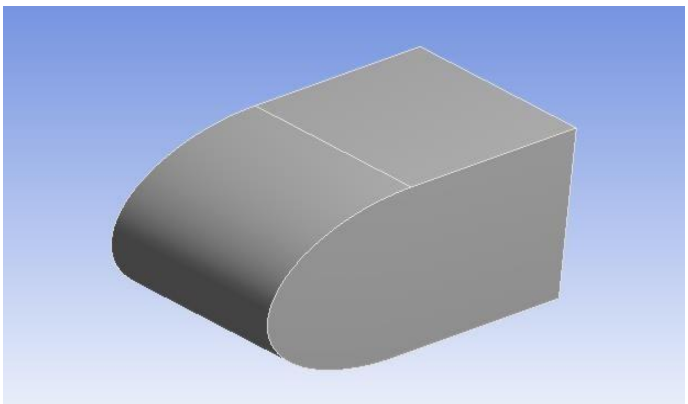


Fig - 4: Elliptical inlet face ensure clean flow at any angle of attack

4.3 Meshing and Pre-Processing

Meshing process was carried out by using ANSYS Meshing. The mesh is created using several sizing function such that the result found to be accurate without any errors. Mesh generation is the patch Conforming Tetrahedral Meshing Method. It meshes the edges at first and then the volume. To get the better results at the surface of the wing, the boundary layer meshing is done in the wing section. The mesh is then done using parallel meshing process using all the possible systems core for fast processing of mesh generation. The mesh details of the winglet design are mentioned as follows.

S.No	Mesh Details	Values
1	Number of Nodes	1365525
2	Number of Elements	4091575
3	Mesh metric	None
4	Element type	Unstructured tetra

Table - 1: Meshing Statics

A boundary was created to capture the fluid and to create the Grids for the surface on each side of the winglet for solving the symmetry of wing section. The sizing function scheme will reduce the number of elements exported to FLUENT and also reduce the time for computational analysis.

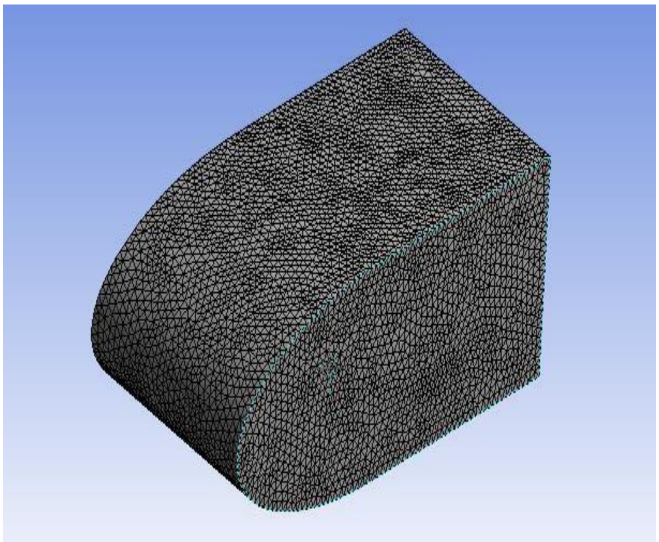


Fig - 5: Patch Conforming Tetrahedral Mesh

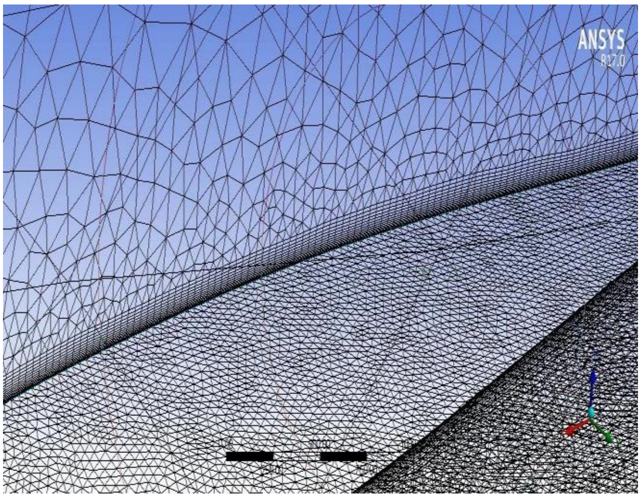


Fig - 6: Boundary Layer Mesh

4.4 Boundary Condition

Computational Simulation have been carried out by fluent solver using finite volume approach with pressure based solver at steady state, Spalart - Allmaras turbulence model is considered with air ideal gas on the material.

S. No	Conditions	Settings
1	Solver	Pressure based solver
2	Turbulence Model	Spalart Allmaras
3	Air	Incompressible
4	Inlet Velocity	70 m/s
5	Inlet Temperature	300 K
6	Outlet Pressure	101325 Pa
7	Solution Method	Coupled
8	Gradient	Least Squares Cell
9	Pressure	Second Order
10	Momentum	Second Order upwind
11	Modified turbulent viscosity	Second Order upwind

Table - 2: Flow Conditions and Solver Settings

5 Result and Discussion

The analysis is done for 7 angles of attack such as $0^0, 4^0, 8^0, 12^0, 16^0, 20^0, 24^0$ respectively for both the conventional and split blended wings.

5.1 Path Line

The Static Pressure contour images for the conventional wings are as follows,

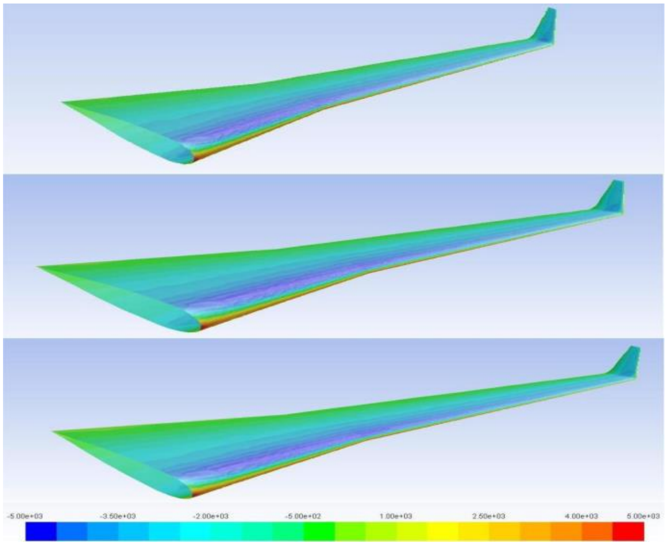


Fig - 7: Pressure distribution for 0^0, 4^0,8^0 winglets

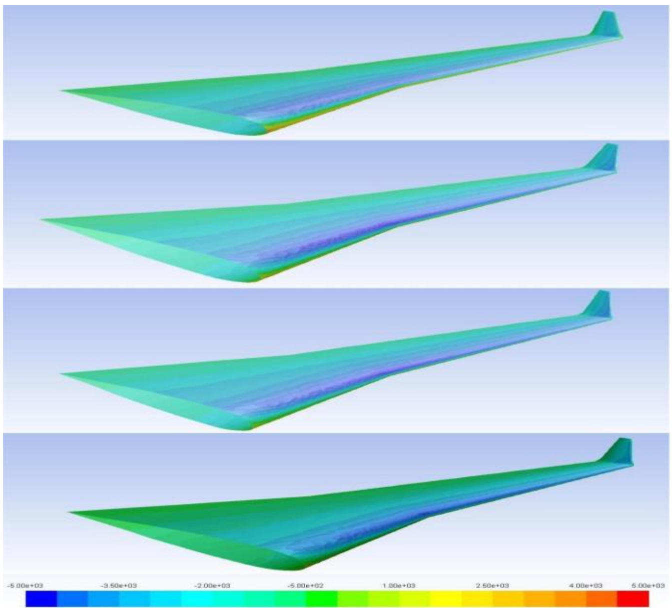


Fig - 8: Pressure distribution for 12^0,16^0,20^0,24^0 winglets

The C_L and C_D values for the regular conventional blended winglets are as follows,

S.No	AOA	C_L	C_D	C_L / C_D
1	0	1.87E-03	8.31E-05	22.4817
2	4	2.19E-03	1.44E-04	15.2324
3	8	2.50E-03	2.09E-04	11.9676
4	12	2.81E-03	2.58E-04	10.9059
5	16	4.67E-03	2.96E-04	15.7396
6	20	5.58E-03	3.25E-04	17.1797
7	24	5.27E-03	4.25E-04	12.4050

Table - 3: Lift and Drag Coefficient for conventional blended winglets

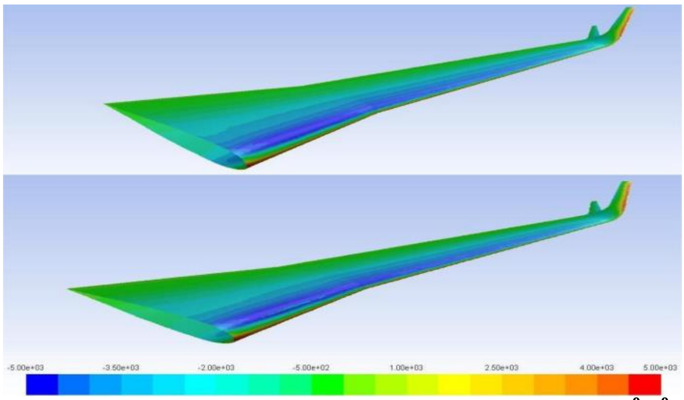


Fig- 9 Static pressure distribution for split winglet for 0^0,4^0

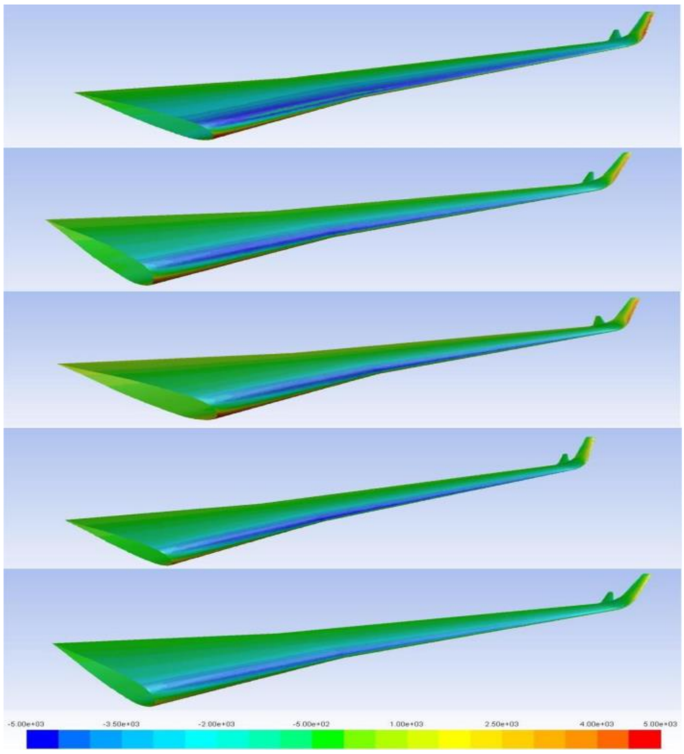


Fig - 10: Static pressure distribution for split winglet for 8^0,12^0,16^0,20^0,24^0

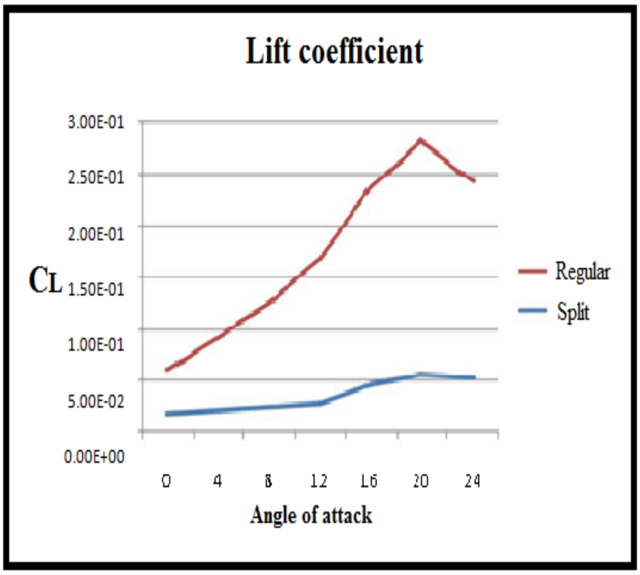
Static pressure contours are plotted and the flow coefficient such as lift and drag values are found out respectively.

S.No	AOA	C_L	C_D	C_L / C_D
1	0	4.21E-02	2.22E-03	18.9402
2	4	7.09E-02	4.73E-03	14.9788
3	8	1.00E-01	7.51E-03	13.3809
4	12	1.40E-01	1.02E-02	13.7433
5	16	1.90E-01	1.17E-02	16.3242
6	20	2.27E-01	1.24E-02	18.2819
7	24	2.90E-01	1.60E-02	11.8750

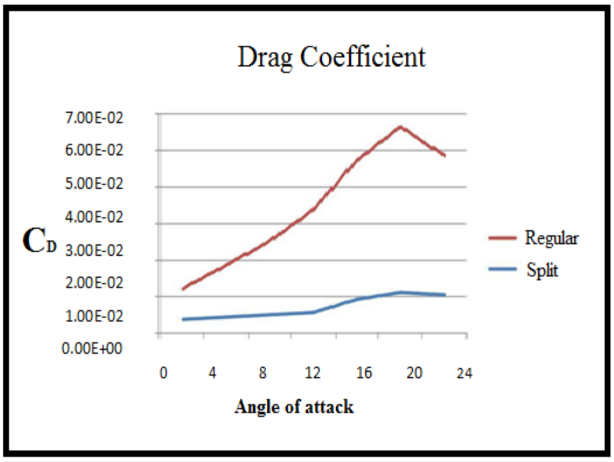
Table - 4: Lift and Drag Coefficient for split blended winglets

5.2 Plots

Based on the found values of C_L vs α and C_D vs α graphs are plotted. These graphs shows the significant improvement of lift coefficient thus reducing the induced drag produced on the wing due to production of lift. The comparison of lift coefficient is shown below.



Graph - 1: Coefficient of Lift Comparison



Graph - 2: Coefficient of Drag Comparison

This drag reduction provided by the blended winglets improves the fuel efficiency and reduce the emission.

- Reduce the engine maintenance costs
- Improve take off Performance
- Lowering the operational cost
- Increase the range Capability
- Increase the cruise altitude

S.No	Load	Mission	Fuel use with winglets	Percentage of fuel saving
1	162	1000	13,386	3.5
2	200	1000	16,975	3.2
3	218	3000	65,288	4.4

Table - 5: Fuel Consumption Comparison

6 Conclusion

This project proposed an idea for developing a new kind of winglet which reducing the induced drag and increasing the flight performance for long range and better fuel economy than currently existing blended winglets. This model is designed and analysed using the computational fluid dynamics to find out the performance of the model. There is a increase in aerodynamic efficiency after the attachment of split blended winglets by adding this type of split blended winglets is to reduce the induced drag and air vortices. This winglet device increases the aerodynamic efficiency in the terms of C_L / C_D. The reduction in drag was proven in this proposal by attaching the split blended winglet at the wing tip. It also increases the interference drag and also the performance of the flight even more.

References

[1] Bhushan B.D, " *Bird Feathers for Induced Drag reduction in turbulent flow",* Journal Of Aircraft.

[2] Bourdin P, Gatto A and Frisewell M.I, "*aircraft Control Via Variable Cant - Angle Winglets",* Journal of Aircraft, Vol 45, No.2, 2008, PP : 414-423.

[3] Cosin R, " *Aerodynamic Analysis Of Multi -Winglets for Low Speed Aircraft",* Journal Of Aircraft.

[4] Faye R, Laprete R, and Winter M, "*Blended Winglets",* Vol 17, No.2, 2002.

[5] Heshman S.M Helal, Essam E Khalil, Osama A Gamal, " *Aerodynamic analyses of Aircraft Blended Winglets Performances",* Vol 19, 2016.

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

[7] Narayan G, Jhon B, " *Effect Of Winglets Induced Tip Vortex Structure on The Performance Of wings",* Aerospace science And Technology, Vol 58, 2016, PP: 328-340.

[8] Roche La.U " *Induced Drag Reduction Using Multiple Winglets",* Vol 2, 2008.

[9] Smith M.J, "*Performance Analysis of a wing with Multi - Winglets",* Vol 12, 2007.

[10] Srikanth G.S.B, "*Experimental Analysis of Multi-Winglets",* AIAA Journal.