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CFD Analysis and Comparision of Spiroid and Dual Feather Winglets

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Abstract: Potential of spiroid and dual feather winglet's are taken into consideration. By using biomimetic abstraction principle of a bird's wingtip feathers, we study spiroid and dual feather winglets which look like extended blended winglets. The dual feather winglets is the study about of advance hybrid winglets design. Considering NACA 2412 airfoil, the wing and winglets have been generated of wing span 28350 mm and wing chord 7320 mm which is the specification of BOEING 737. The purpose of the analysis is to examine aerodynamic characteristics and to scrutinize the performance of winglets at different Angle of Attacks (0, 10, and 15). The CFD simulations are performed. The winglet model is designed using CATIA V5 software. Computational simulation is carried out by FLUENT. The aerodynamic characteristics of the designed winglets are compared.

Keywords: Spiroid winglets, Dual Feather winglets, NACA 2412

I. INTRODUCTION

Wingtip devices are used to increase the efficiency of a fixed-wing aircraft. There are different types of wingtip devices. These wingtip devices reduce the aircraft's drag by recovering partial vortex energy at tip and can increase aircraft handling characteristics.

These devices increase the aspect ratio of a wing without increasing the total wingspan. Increase in span length might decrease the lift-induced drag, but would increase parasitic drag. Wingtip devices increase the lift generated at the wingtips by smoothing the airflow across the upper surface near the wingtip and also improving lift-to-drag ratio.

Wingtip vortices are produced in circular patterns of rotating air left behind a wing as it generates lift. Indeed, vorticity is trailed at any point on the wing where it eventually rolls up into large vortices near the wingtips. Wingtip vortices are associated with induced drag, circulate a downwash, and are a fundamental result of three-dimensional lift generation

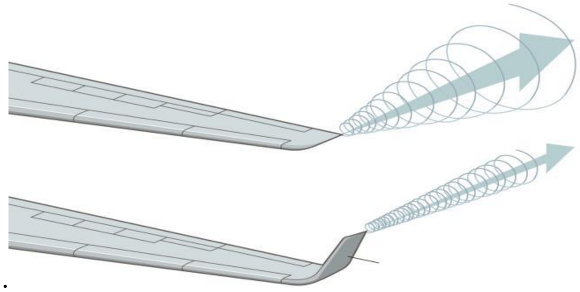

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Fig 1: Effect of vortices with and without winglets.

Spiroid Winglets:

It is a modern closed-loop wingtip device. For spiroid winglets, half of the wing tip chord extends vertically the other half of the chord extends horizontally, and join in a spiral shape. The flow direction on the upper surface of a swept wing is normally from tip to root, but for the wing equipped with spiroid winglets the opposite is true.

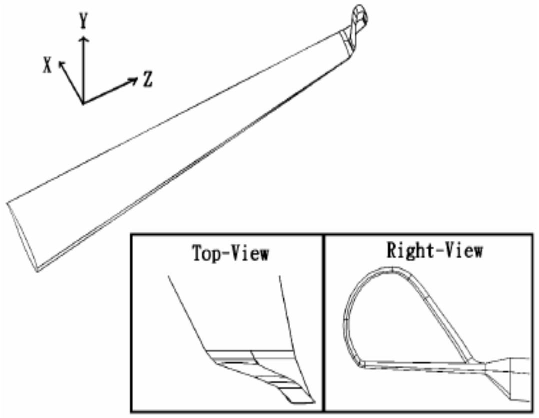


Fig 2: Geometry of wing equipped with forward spiroid winglets.

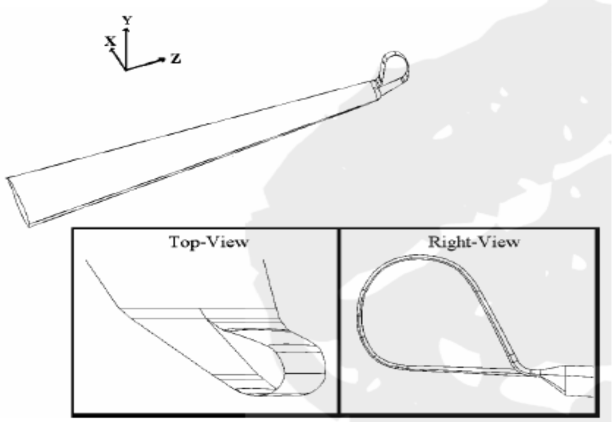


Fig 3: Geometry of wing equipped with after spiroid winglets.

Dual Feather Winglets:

Due to many challenges for increasing the efficiency of flight, Boeing is working on drag reduction at wingtips and came up with hybrid type of winglets which has a hybrid design resembling blended winglets, raked tip and wingtip fence. These are wing tip devices which decrease lift induced drag and provide some extra lift.

Fig 4: Dual Feather Winglets

Angle Of Attack :

Angle of Attack is the angle between the chord line of a wing and the relative wind. As relative wind pass over an airfoil, an aerodynamic forces are produced. This force can be broken down into two components they are lift and drag. The lift produced by an airfoil is the net force produced perpendicular to the relative wind. The drag incurred by an airfoil is the net force produced parallel to the relative wind.

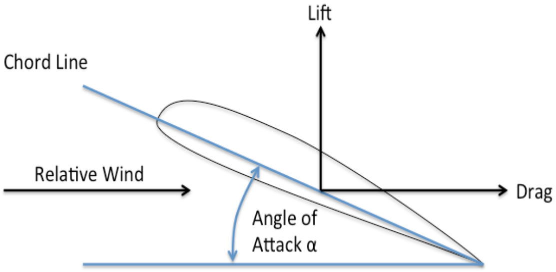


Fig 5: Angle of Attack (AoA).

II. MODELING

A. *wing selection*

Wing and winglets are designed by using CATIA V5 software using the design characteristics as follows.

Wing span	28350 mm
Tapper ratio	4.57
Root chord length	7320 mm
Tip chord length	1600 mm

B. *Airfoil selection*

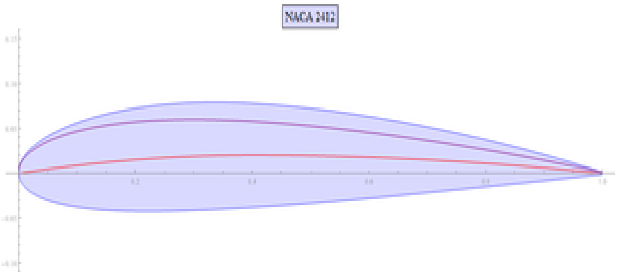


Fig 6: NACA 2412

NACA 2412 airfoil has been considered for the wing. NACA 2412 is defined as Max thickness 12% at 30% chord. Max camber 2% at 40% chord

C. *Modeling of wing and winglets*

Wing tip and root airfoil coordinates are imported to CATIA V5 and then using pad tool wing is generated.

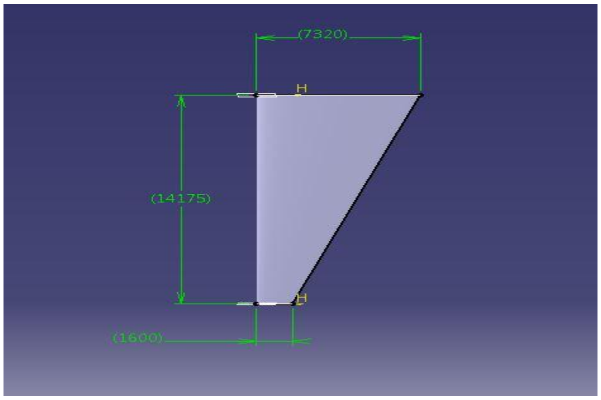
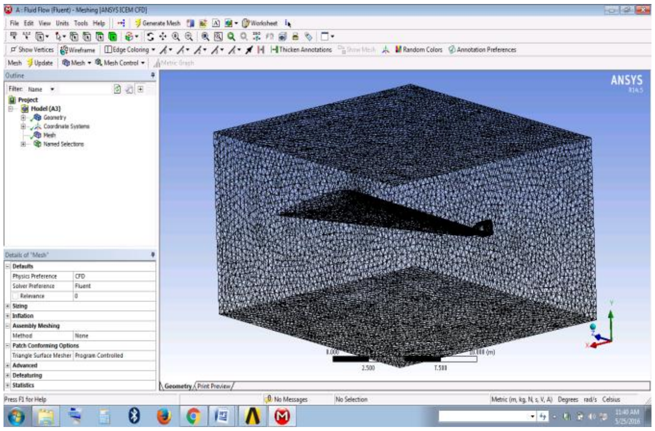


Fig 7: wing model in CATIA

III. SIMULATION

A. Mesh

Design is imported to ANSYS WORKBENCH in (.igs) format to generate mesh. A domain of 5*5*5 m^3 is created and then mesh is generated. In total 6 meshes are generated at a different Angle of Attack like 0, 10 and 15 deg for both the winglets.



Details of "Mesh"

Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Inflation	
Assembly Meshing	
Method	None
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Defeaturing	
Statistics	

Fig 8: mesh of spiroid winglets at 0 AoA

B. *Analysis*

ANSYS fluent flow fluid is used to solve the problem. The solver used for solving the model is pressure based solver. Inlet is initialized as velocity inlet, outlet as pressure outlet and all other walls of domain as wall. The nonlinear governing equations were solved iteratively until the solution converged.

Inlet velocity	150 m/sec
Outlet pressure	101325 Pa

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IV. RESULT AND DISCUSSION

Computational results of velocity, dynamic pressure and static pressure at 0, 10, and 15 AoA for both dual feather and spiroid winglets are tabulated below.

	Spiroid winglets		**Dual feather winglets**	
	Min	***Max***	***Min***	***Max***
Velocity	1.84e+00	2.44e+02	4.26e+00	2.02e+02
Static pressure	-2.48e+04	1.48e+04	-3.53e+04	1.43e+04
Dynamic pressure	2.07e+00	3.66e+04	1.1e+04	2.49e+04

Table 1: at 0deg AOA.

	Spiroid winglets		**Dual feather winglets**	
	Min	***Max***	***Min***	***Max***
Velocity	1.05e+00	5.51e+02	1.56e+00	3.49e+02
Static pressure	-1.9e+05	1.66e+04	-6.58e+04	1.48e+04
Dynamic pressure	6.71e-01	1.86e+05	1.50e+00	7.46e+04

Table 2: at 10deg AoA.

	Spiroid winglets		**Dual feather winglets**	
	Min	***Max***	***Min***	***Max***
Velocity	1.05e+00	5.51e+02	1.13e+00	4.60e+02
Static pressure	1.59e+04	1.59e+04	-1.36e+05	1.57e+04
Dynamic pressure	2.05e-01	1.25e+05	7.79e-01	1.29e+05

Table 3: at 15deg AoA.

A. Velocity contours

The following are the velocity contours of spiroid and dual feather winglets.

i) At 0 deg AoA

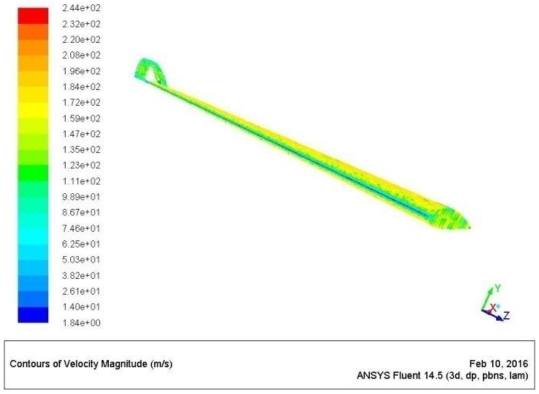

Fig 9: velocity contour of spiroid winglets at 0 deg AoA.

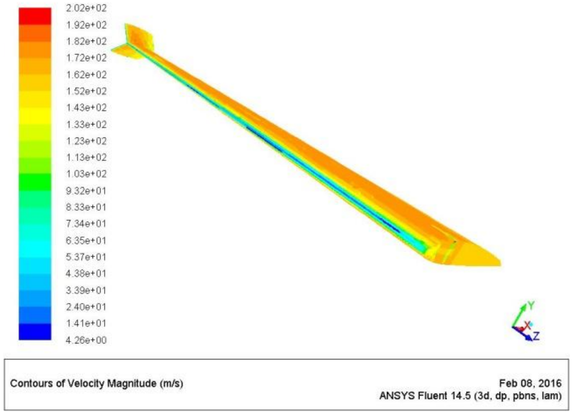

Fig 10: velocity contour of dual feather winglets at 0 deg AoA

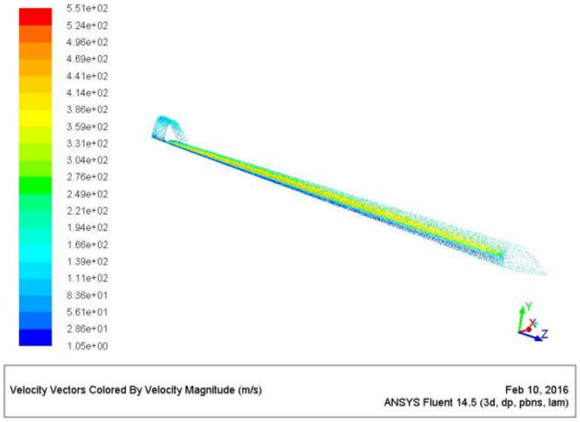

Fig 11: velocity contour of spiroid winglets at 10 deg AoA.

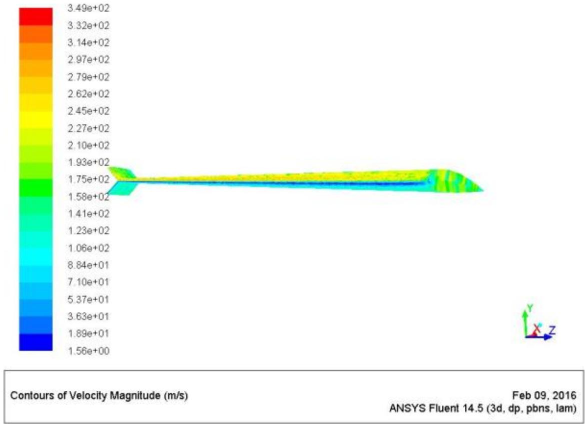

Fig 12: velocity contour of dual feather winglets at 10 deg AoA.

B. Dynamic pressure countours

The following are the dynamic pressure contours of spiroid and dual feather winglets at 0, 10 and 15.

i) At 0 deg AoA

Fig 13: dynamic pressure contours of spiroid winglets at 0 deg AoA.

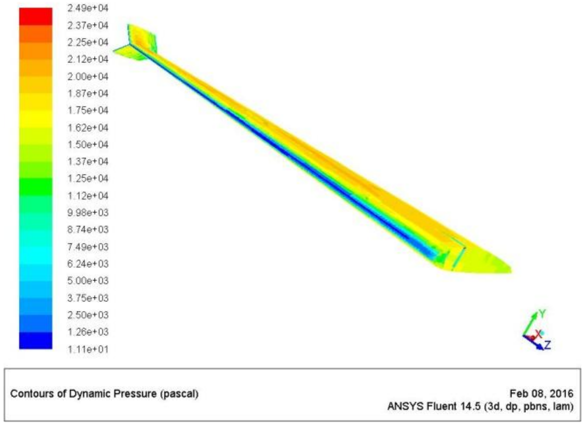

Fig 14: dynamic pressure contours of dual feather winglets at 0deg AoA

C. *Static pressure*

The following are the static pressure contours of dual feather and spiroid winglets at 0, 10 and 15. The contours of all the angle of attack are listed in the table.

i) At 0 deg AoA

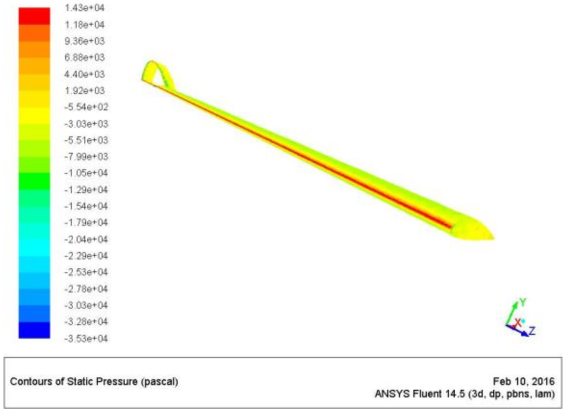

Fig 15: static pressure contour of spiroid winglets at 0deg AoA.

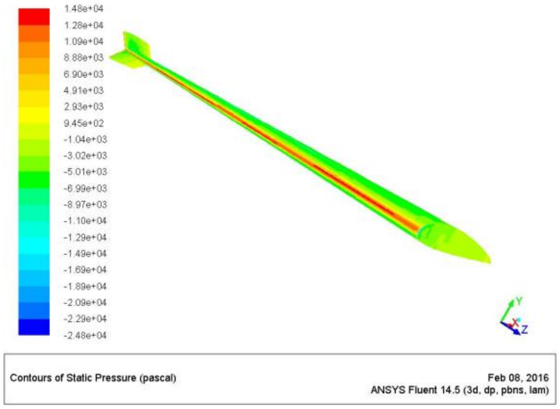

Fig 16: Static pressure contour of dual feather winglets at 0deg AoA.

D. *Lift (L) to Drag (D) ratio*

Lift and drag forces are calculated using L= Ncos(α) – Asin(α) and D= Nsin(α) + Acos(α) Where

- N is normal force
- A is axial force
- α is the AoA

Normal and Axial forces are directly calculated from ANSYS fluent by using (N, A) lift and drag are determined.

AoA	**Spiroid winglets (L/D)**	**Dual feather (L/D)**
0	19.99	12.26
10	8.09	16.61
15	1.09	1.11

Table4: L/D ratio of spiroid and dual feather.

V. CONCLUSION

The present study serves as initial investigation on the aerodynamic effects of Dual Feather winglets and Spiroid Winglets configuration as a result better winglets will be taken into consideration. The results presented in this study reveal certain parameters like velocity, dynamic pressure, static pressure and lift to drag ratio based on which comparison is done.

Spiroid winglets has higher pressure and high velocities at different AOA's whereas Dual Feather winglets are producing less pressure values and feasible velocities at different AOA's. However as per Bernoulli's principle velocity is inversely proportional to pressure and to get better lift, pressure difference is needed which is more in Spiroid Winglets. However, in Dual Feather winglets velocities turned out to be more.

Alternatively, comparing Lift to drag ratio spiroid winglets has feasible L/D ratio. So we conclude that spiroid winglets is better than dual feather.

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