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Numerical Investigation of Double Blended Winglets in Lighter Aircrafts

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ABSTRACT: A winglet is used to increase the efficiency of an aircraft by reducing the lift induced drag which is caused by wingtip vortices. Aircraft has several sources of drag: profile drag, induced drag, the effect caused by high speed aerodynamics. Winglets function to minimize induced drag. The drag analysis of a typical aircraft indicates that lift-induced drag account for up to 80-90 % drag during take-off and 40% of drag during cruise. The motivation for this project is to elaborate comparison between wing models. The project is carried out by modelling two wing models i.e. wing without winglets and wing with double winglets in CATIA V5 design software. The models are then meshed and CFD analysis is done with the help of ANSYS software. The coefficient of lift, coefficient of drag and lift to drag ratio are obtained from analysis and are compared. The wing with double winglet wing has more lift to drag ratio compare to wing without winglet. Thus the wing with double blended winglet increases the efficiency of aircraft which in turn increases the performance.

KEYWORDS: Double blended winglets, Drag, CATIA V5, and ANSYS Fluent.

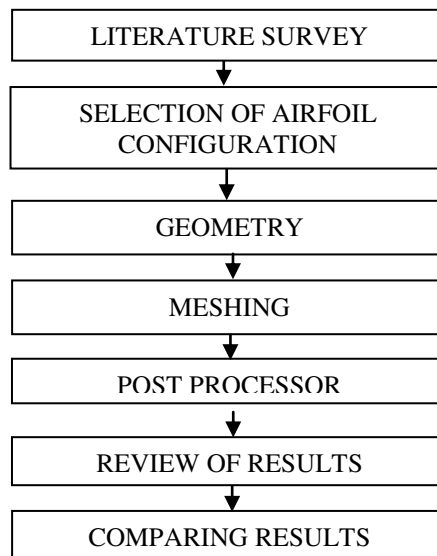
I. INTRODUCTION

The aircraft's performance can be improved by attaching a winglet at the tip of the wing. Winglet increases the effective aspect ratio of the wings by adding significant stress on structure and weight [1]. Rotational motion of the fluid is known as vortex which consists of strong low pressure region as its core. This vortex produced by aircraft is more complicated than unforeseen turbulence in the air. Such vortexes may induce a large rolling movement and are sometimes the cause of loss in maneuverability control which can cause fatalities. These are induced drag in aircraft. Winglets are designed to reduce induced drag. The winglet decreases vortex drag by reducing wingtip vortices [2]. NACA2412 wing profile wing with a winglet was observed to reduce 4 to 10% of induced drag and increase in ratio of lift to drag compared to the wing without winglets [3]. The wing was modeled in CATIA design software. Analysis is carried out in ANSYS Fluent software [4, 5]. A winglet with improved design at a certain cant angle can lower the induced drag by reducing wingtip vortices in turn giving better performance [6]. The research has been carried out on conventional shape of winglets taking inspiration from bird wings. This research can be focused on multiple winglets on same wing with optimum cant angle [7]. The analysis was carried out for winglets with different cant angles and the optimum cant angle was found to be 30° which give better aerodynamic characteristics of overall aircraft by increasing lift to drag ratio [8]. C_L and C_D results of NACA 2412 are computed in ANSYS Fluent [9].

Many researchers have carried out flow analysis on aircraft wings for different NACA series with and without winglet. Their study says wings with winglets gives better lift and less drag due to reduction in strength of wingtip vortices. To minimise the wingtip vortices I found a design of double blended winglets in lighter aircrafts. A very few researchers have carried out work on this in commercial aircrafts. So this concept motivated me to carry out the analysis on double blended winglets wing, to understand the aerodynamic significance of fluid using the software CATIA V5 and ANSYS fluent. This work focuses comparing the performance of NACA 2412 wing without winglets and wing with double blended winglets. To validate, the results obtained are compared with the results of ArnavKulshreshtha et.al [9]. It is found that the lift drag ratio is increased by 5% at 6° angle of attack for wing with double blended winglets compared to without winglet wing model.

II. METHODOLOGY

The methodology of this work is represented in flow chart and as mentioned in the flow chart historical studies are the first step in the starting project. The models are modeled using CATIA V5 and are imported to ANSYS Fluent to analyse the aerodynamic forces at different angle of attack. Finally the results of both the models are compared.



III. MODELING AND MESHING

NACA 2412 coordinates are obtained from airfooltool website and imported to CATIA V5, where the wing without winglet and double blended wingletswing are modeled. Table 1 shows wing dimensions of model

Table 1: Wing dimensions

SLNO.	PARAMETER	VALUES
01.	Wing span	200mm
02.	Wing root chord	200mm
03.	Wing tip chord	52mm

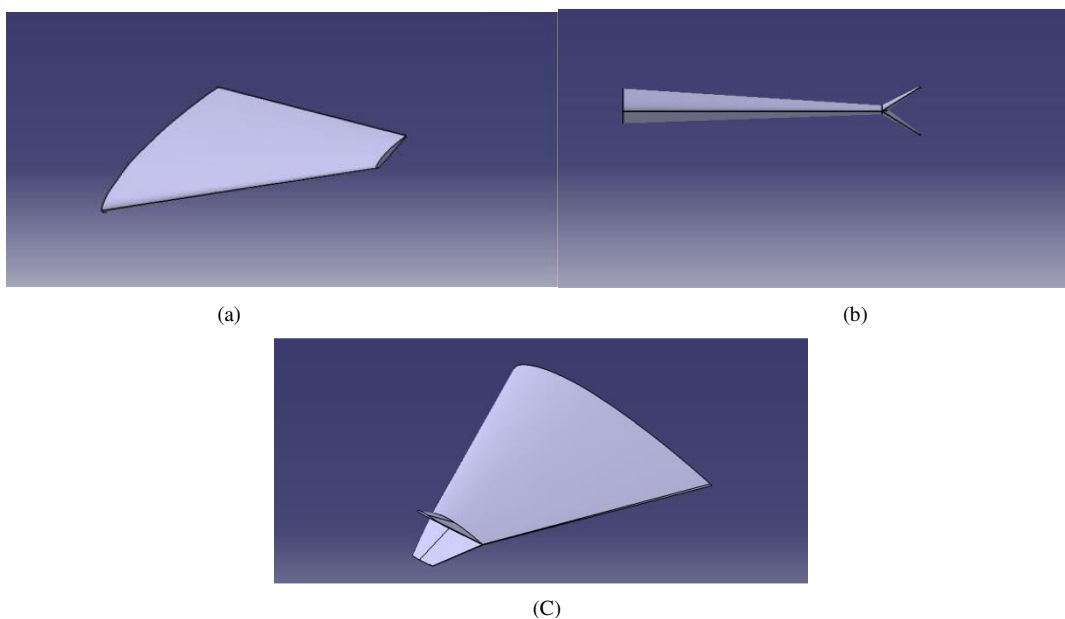


Fig 1:Wing models designed in CATIA V5 (a) Wing without Winglets(b) Front view of wing with double blended winglets (c) Isometric view of Wing with double winglets model.



Further the modeled wings are imported to ANSYS Fluent for meshing and analysis. Quality of mesh for both the models is maintained using factors such as skewness, aspect ratio and orthogonal quality. The number of nodes and elements are:

Table 2: Nodes and elements after meshing

Wing Models	Nodes	Elements
Wing without winglet	89893	464901
Wing with double blended winglets	92718	515102

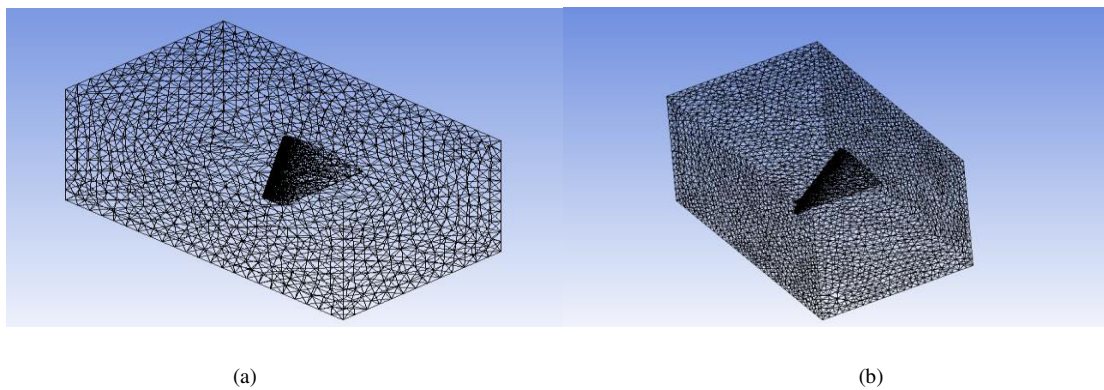


Fig 2: Meshed geometry (a) Wing without winglets mesh (b) Double blended winglets wing mesh

IV. RESULTS AND DISCUSSION

Analysis is carried out with k-epsilon flow model. To validate, the results obtained by the analysis of wing without winglet with the results of C_L and C_D determined by ArnavKulshreshtha et.al [9] for NACA 2412 at angles of attack from -5^0 to 20^0 in step of one. Since maximum lift to drag ratio was determined at around 5^0 the angle of attack for this work is taken in the range of 0^0 to 10^0 . The pressure contours, lift curve, drag curve and lift to drag ratio curve for present study is obtained. Graphs are plotted for C_L and C_D results are compared.

Table 3: Comparison of C_L

AOA	C_L ArnavKulshreshtha et.al [9]	C_L (without winglets)	C_L (with Double Blended Winglet)
0	0.314	0.306	0.445
2	0.711	0.701	0.856
4	1.185	1.067	1.251
6	1.419	1.457	1.725
8	1.874	1.765	2.066
10	2.337	2.199	2.568

Table 4: Comparison of C_D

AOA	C_D ArnavKulshreshtha et.al [9]	C_D (without winglets)	C_D (with Double Blended Winglet)
0	0.017	0.016	0.021
2	0.027	0.030	0.033
4	0.043	0.044	0.048
6	0.064	0.053	0.060
8	0.090	0.083	0.093
10	0.125	0.109	0.120

Table 5: Comparison of C_L/C_D

AOA	C_L/C_D ArnavKulshreshtha et.al [9]	C_L/C_D (without winglets)	C_L/C_D (with Double Blended Winglet)
0	17.444	19.125	21.190
2	26.333	23.366	25.94
4	27.558	24.25	26.27
6	22.1718	27.49	29.00
8	20.822	21.265	22.21
10	18.475	20.174	21.4

The results obtained are tabulated in Table 3, 4, 5 which compares the parameters of wing without winglets and double blended winglets wing with results of the numerical work carried out by the researcher ArnavKulshreshtha et.al [9].

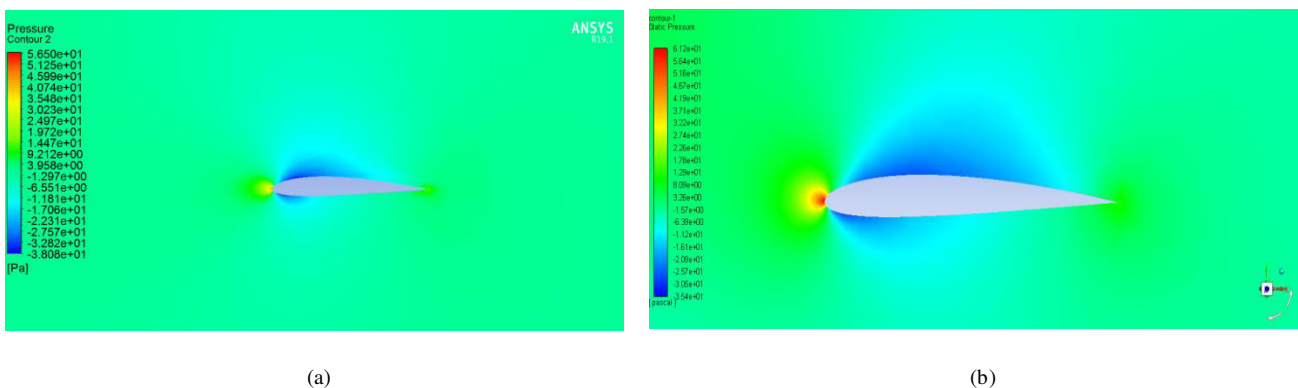


Fig 3. Pressure contours at 6° angle of attack: (a) Wing without winglets (b) Double blended winglets wing.

Fig. 3 shows the pressure contours of wing without winglets and wing with double blended winglet at 6° angle of attack where ratio of lift to drag is maximum. As angle of attack increases the point of minimum pressure moves forward and the pressure gradient over the wing increases. This increase in pressure gradient increases the pressure differential between upper surface and lower surface which results in increase in lift of an aerofoil.

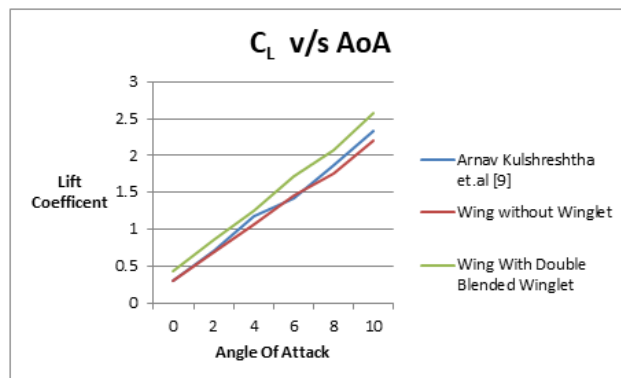


Fig 4: Resultant graph of C_L v/s angle of attack Curve

As indicated in Table 3 and Fig. 4, it is found that as the angle of attack increases the lift increases for both the models. The same trend is found by ArnavKulshreshtha, et.al [9] in their analysis of wing. For each angle of attack the double blended winglets have more lift as the added winglets increases the effective aspect ratio which in turn increases the lift of the wing. Hence there is a significant increase in coefficient lift for a double blended winglet wing compared to a without winglet wing.

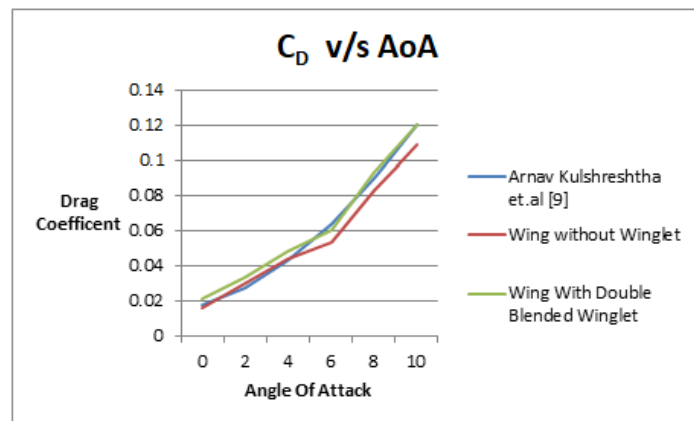


Fig 5: Resultant graph of C_D vs angle of attack Curve

From the Table 4 and Fig. 5 indicates that drag increases with increase in angle of attack for both wing without winglets and double blended winglets wing. The same trend is followed even in the work carried out by ArnavKulshreshtha, et.al [9]. Drag increases with increase in the angle of attack as the frontal area exposed to air stream increases which restricts the flow. Since winglets are mounted on wingtips there is marginal increase in coefficient of drag is seen in wing with double blended winglets compared to the wing without winglets. But the marginal increase in drag is compensated by relatively more increase in lift.

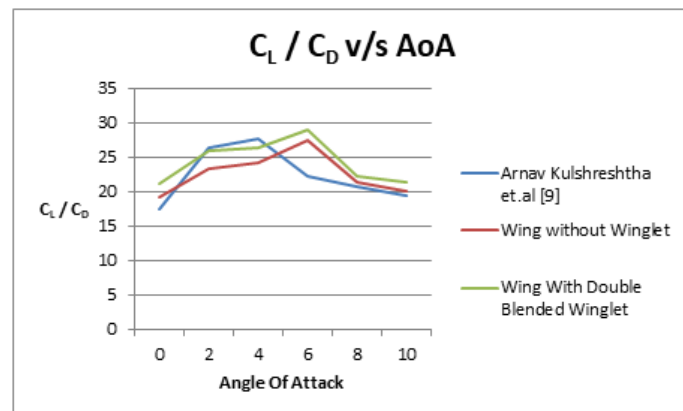


Fig 6: Resultant graph of C_L/C_D vs angle of attack Curve

From Table 5 and Fig. 6, it is indicated that C_L/C_D increases with increasing angles of attack. For wing without winglets and double blended winglets wing the C_L/C_D increases with increasing angle of attack. At 6° angle of attack value of C_L/C_D is maximum. The C_L/C_D gradually decreases after 6° angle of attack, for both wing without winglets and double blended winglets wing models. The same trend is followed in the results of ArnavKulshreshtha, et.al [9]. This is due to separation of flow from upper surface which increases drag greatly relative to the raise in lift.

In every angle of attack double blended winglet has more C_L/C_D compared to wing without winglets. It is also found that double blended winglets has 5% more C_L/C_D compared to wing without winglets. The comparison of C_L/C_D makes clear that double blended winglets wing model is more efficient than the wing without winglets as the former increases overall lift to drag ratio by 5%, which in turn increases overall performance of the aircraft.

V. CONCLUSION

The results of the current study demonstrated that winglets are now becoming into a significant and common tool for enhancing performance in the current, hypercompetitive aircraft market. The analysis of with and without winglet cases promises that winglet installation increases lift to drag ratio. In contrast to the typical designs, this project suggests wing designs with a double blended winglet and wing without any winglets for lighter aircrafts.

1. The wing models have been modeled in CATIA V5.
2. Mesh optimization is obtained by considering skewness, aspect ratio and orthogonal quality.
3. Both mesh optimization and analysis is carried out in ANSYS.
4. The C_L/C_D ratio from analysis is maximum at 6° angle of attack for both wing models beyond which the ratio decreases because of flow separation occurring on the upper surface of wing.
5. The results obtained for both the wing models are compared. It has been noticed that wing with double blended winglet has better lift to drag ratio compare to other model.
6. An aircraft's performance will be greatly improved with an improved double blended winglet design.

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