Research Article

Design and Computational Analysis of Winglets

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Abstract: The primary goal of this project is to learn and analyse the aerodynamic performance of wings and various types of winglets and wingtip devices. The objective of this study is to improve a model for various types of winglets and wingtip devices using the software SOLIDWORKS, And Fluent Analysis using the software ANSYS. The best performing aerofoil in terms of aerodynamic efficiency, NACA 64-215, was chosen for wing construction. A wing which is without winglets was simulated, followed by a wing with various winglets at different Cant angles. To determine the aerodynamic efficiency, a wing with a blended winglet and a raked winglet was simulated. In order to found a more efficient wing with winglets, designs of Blended and Raked winglets are modified, and comparison of the performance of winglets by varying with different cant angles, 30° and 60° were performed. As a result of this work, it was concluded that adding a winglet to a wing increases its aerodynamic efficiency in terms of C_L/C_D.

Keywords: Winglets, Wingtip Devices, Blended Winglet, Raked Winglet, Lift, Drag, Vorticity, Co-efficient of Lift, Co-efficient of Drag

1.1 Introduction to Winglets

Current global environmental issues such as rising aviation fuel costs and global warming have forced airlines to make adjustments. In this way, manufacturers and commercial airlines will strive to minimize the environmental impact of aviation, and ideally improve the efficiency of the use of aviation fuel during flight. Airplanes are efficient and fast means of transport and require a huge volume of fuel. Therefore, aviation artists are increasingly paying more attention to how to reduce fuel consumption and improve flight efficiency. The key to achieving this goal is to reduce traction and increase lift. In particular, reducing air resistance is an important aspect of improving the performance of large transport aircraft (1). Develop an aircraft configuration that uses less fuel. Fuel consumption per seat mile is highly desirable. Aviation designers are working to improve the overall efficiency of aircraft, which will benefit aircraft manufacturers and airlines. One of the most difficult aspects of the aircraft design process is reducing the overall air resistance to an less acceptable level. There have been several studies of procedures to reduce the traction induced by abstraction. F.V. British scientist Lanchester invented the endoscope in the late 19th century. The induction resistance can be reduced by using the plate technique (3). The fusion wing can effectively block airflow in the wing range and form a vortex. The structure of the vortex can be damaged, the induction resistance can be reduced, the air resistance can be reduced, aerodynamic efficiency can be improved, and vehicle fuel consumption can also be reduced (1). Screens are one of the most notable fuel saving technologies in aviation. The wing, which is a small wing or a vertical projection of the knee, increases the efficiency of the aircraft by reducing the air resistance caused by the forward slope of the wing, which increases the lift-to-draft ratio (L/D). The wing works by increasing the effective elongation of the wing without significantly increasing the load on the structure. Frederick W. Lanchester invented the winglet concept in the late 19th century (3). His research shows that wingtip retraction in high lift conditions can be reduced by adding a vertical surface to the wingtip. In 1897 he patented the term "end plate". However, its design created a large flow split, which resulted in a significant increase in airflow resistance, making it inefficient in cruising conditions. Dr. Sedan. Richard Whitcomb, an aeronautical engineer at NASA's Langley Research Center, built a small vertical assembly on a Boeing KC-135A aircraft and conducted experiments in 1974 (3). The results suggested that the force of the vortex could be reduced if the wing slide had a properly designed vertical wing-shaped surface.

2.1 History of Winglets

British aerodynamics scientist Fredrick W. Lanchester first offered a patented wingtip device in 1897 (3). The fore wing vortex is a circular air pattern that forms when the plane is lifted. This type of abstraction is basically called lift-induced vortex. Because, the lift is main cause due to this circular shape. The theory of vortex formation is that when air flows from high to low pressure due to the pressure difference in between the top and bottom of the wing, the flow moves from bottom to top and zero out, resulting in a differential pressure (2). Despite the reduction in guided draft, his theory was unable to reduce the overall draft of the aircraft. In cruise conditions, the increase in tackle is greater than the decrease in induced draft. Dr. Whitcomb conducted research at NASA's Langley Research Center in July 1976 and developed the winglet technology concept. According to Whitcomb, the wing is a small, vertical wing-like structure that extends from the front of the wing to reduce induced traction compared to other wing units or extension units. In his study, he also reported that the wing reduced induced traction by 20% compared to high elongation and improved traction. In the case of a winged wing, these nonlinear effects can be very weak due to the short side and small changes in angular deflection compared to the incident flow on an almost vertical surface. These results suggest that the wings may have additional wings on top of the flat wing, and more importantly, the potential flow method is more suitable for analyzing the wing wine composition than the flat wing (4). 1994 Aviation Partners Inc. (API) has developed an improved wing design called mixed wing. A patent for the blended wing was filed by Louis B. Gratzer of Seattle, and the purpose of the wing is to reduce the resistance to interference caused by the sharp edges seen on the Whitcomb wing. Gratzer also holds a patent for a helical helical wing, which was obtained on April 7, 1992 (3). Subsequently, in 1996, La Roche invented Switzerland and received a patent for the "wing grille" design. The main purpose of all of the above developments was to reduce the induced resistance by scaling the resulting vortex.

3. Methodology

3.1 Introduction

The process of model creation, including model creation and implementation, is called modeling. This model resembles a real system, allowing analysts to predict the effort required to fix the system. In other words, modeling is the process of creating a model that represents a system and its properties. Model design is more flexible as a wide range of software is available. Winglet was efficiently modeled and designed using SolidWorks software.

3.2 Solid works

SolidWorks is acomputer aided design (CAD) computer aided engineering (CAE) and simulation software that is widely used in the modern world. SolidWorks is a solid mediator with a feature-based parametric approach. Solid works was launched in November 1995 with the Works version of Solid 95 and the latest version of Solid 2021. Artwork is usually a 2D drawing of the first step in creating a SolidWorks model. Geometries such as points, lines, circles, cones (except hyperbolic) and richness form the sketch. Dimensions are included in the sketch to describe the scale and location of the geometry. Peace, reciprocity, orthogonality, and concentration are all functions that are described as relationships. Since Solid Works is parametric, dimensions and conditions define geometry, not vice versa. Boundary conditions can be expressed by right-clicking on the geometry. The dimensions of the sketch can be changed independently or under conditions with other parameters inside or outside the sketch. Friends are like sketching addresses in the service. Assembly Friends define relationships similar to individual parts or functions, so you can easily create services as sketch relationships define relationships as tangents, planes, and tangents to sketch geometry.

3.3 Geometry (3-D CAD Modelling)

In SolidWorks the wing and winglet is modelled. The aero foil used was a 5-digit NACA series, NACA 64-215, as shown in Figure 1.

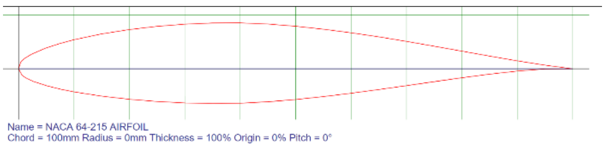

Figure 1. NACA 64-215 Aerofoil Section

Figures below illustrates the CAD models of wing-winglet configurations generated in SolidWorks.

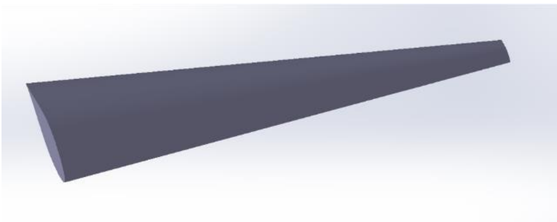

Figure 2.1 Wing without Winglet

The blended winglet uses the basic configuration of a plain wing with an augmented aerofoil profile at the wing's tip. The winglet is built with different cant angles of 30° and 60° to decide the best design characteristic. Figure 2.2 & 2.3 illustrates the various cant angled winglet layouts.

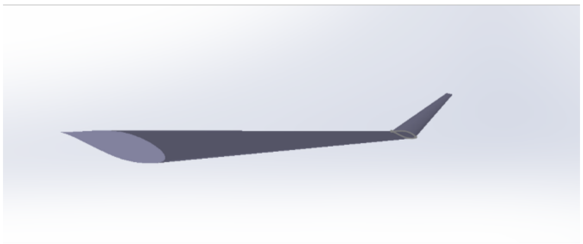

Figure 2.2 Wing with Blended Winglet at 30^0 Cant Angle

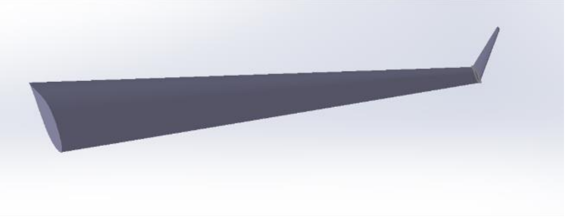

Figure 2.3 Wing withBlended Winglet at 60^0 Cant Angle

The Raked winglet uses the basic configuration of a plain wing with an augmented aerofoil profile at the wing's tip. Figure 2.4, 2.5 & 2.6 illustrates the various cant angled winglet layouts.

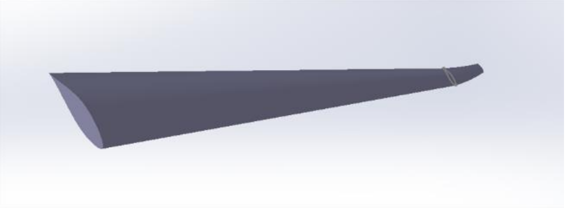

Figure 2.4 Wing with Raked Wingtip 1

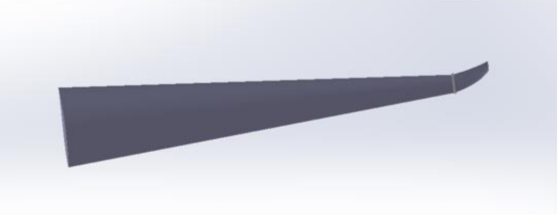

Figure 2.5 Wing with Raked Wingtip 2

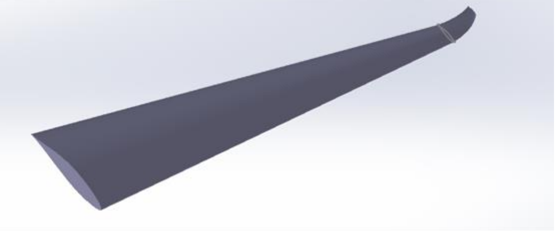

Figure 2.6 Wing with Raked Wingtip 3

3.4 Computational Domain

For all Wing model’s Rectangular domain is used as Shown in the Figures below

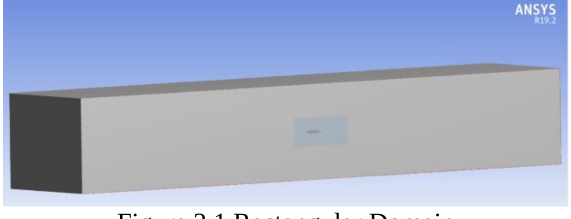

Figure 3.1 Rectangular Domain

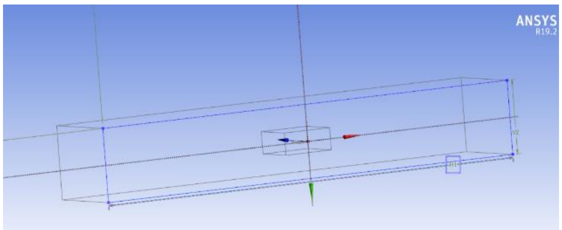

Figure 3.2 Rectangular Domain Wireframe

The above picture shows the geometry of the rectangular domain with length 250 cm, breadth 40 cm and width 50 cm.

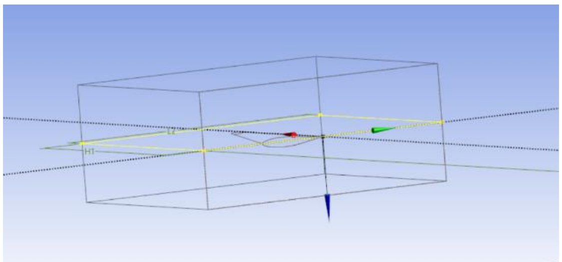

Figure 3.3 Inner Domain

The above picture shows the geometry of the inner domain with length 28 cm, breadth 25 cm and height 12 cm. The dimensions of the Rectangular Domain configurations are illustrated in Table 1

Table 1

H1	250 cm
L4	125 cm
L6	20 cm
V2	40 cm

The dimensions of the Inner Domain configurations are illustrated in Table 2

Table 2

H1	25 cm
L2	28 cm
L7	14 cm

3.5 Mesh Generation

The mesh generated is Unstructured tetrahedral mesh because its ability to mesh easily for complex geometry and Arbitrary positions. The mesh has been refined around the aerofoils, with additional refinement around the leading and trailing edges, while the mesh in the rest of the computational domain is coarse. In addition, values for Inflation layer thickness, Inflation layer number, and base size have been defined. The meshing of the 3D computational domain is performed with the tools available for computations as well as time constraints in mind. Mesh refinement was achieved using three separate mesh refinement choices. The base size is based on the approximate cell size calculation on the wing surface. The maximum cell size is defined as the largest distance on the surface of the computational domain in the 'Inlet' upstream region. The mesh of the computational domain is shown in below Figures.

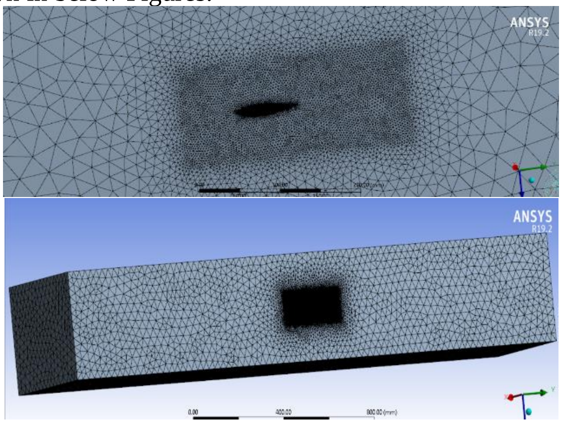

Figure 4.1 Completed mesh wing and domain

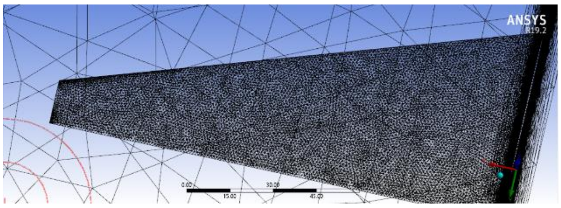

Figure 4.2 Mesh generation on wing surface

The above picture shows the face meshing on the wing surface with the element size of 1mm.

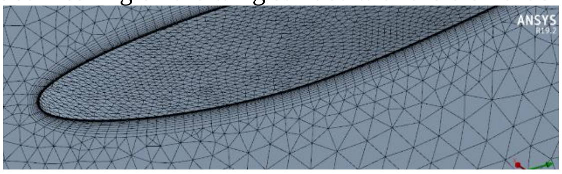

Figure 4.3 Inflation Layers

The above picture shows the first layer of inflation. Using the Inflation feature in ANSYS Fluent, you can achieve cell/element stacking in the direction normal to the boundary. Essentially, you can inflate the mesh with several layers from the boundary's surface until the thickness of the boundary layer is completely covered.

Table 3 Mesh Properties

Elements Size	30 mm
No. of Nodes	5932015
No. of Inflation Layers	16
Total Thickness	2 mm

3.6 Boundary Conditions

A physics continuum is a set of physics models, such as flow solver forms, materials types, time models (steady, unsteady), turbulence types, and so on. The following boundary requirements have been investigated for wing designs: Table 4 Illustrate the following

Table 4

Domain	Boundary Conditions
Inlet	Pressure Far field
Outlet	Pressure Far field
Wing	No slip wall

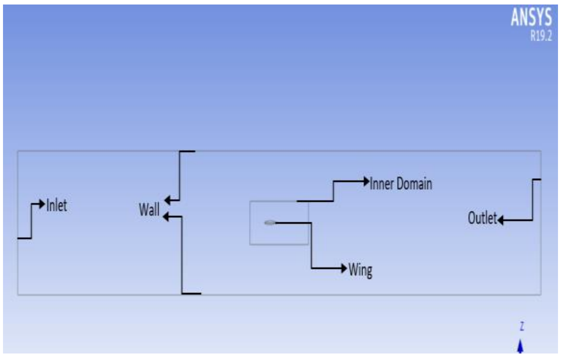

Figure 5.1 Boundary Conditions.

The Spalart-Allmaras Turbulence Model was created with aerodynamic flows in mind. From a viscous sublayer formulation to a logarithmic formulation based on y+, the formulation blends. As a result, no strongly non-linear damping functions are used in the laminar/viscous sublayer modeling.

4. Results and Discussion

4.1. C_L, C_D

The results of the CFD simulations were comparable. The outcomes of the 3-D analysis A wing with winglets were compared to a wing without winglets at various cant angles. The focus of thisstudy was on the aerodynamic characteristics, i.e., C_L, C_D

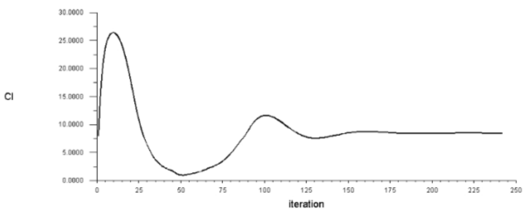

Figure 6.1 Co-efficient of Lift

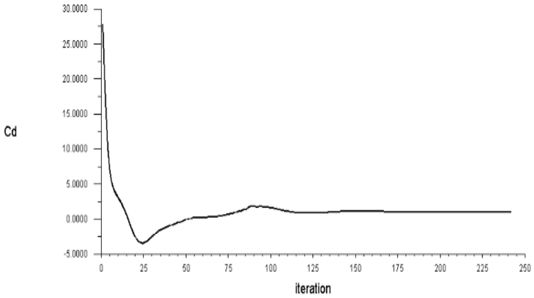

Figure 6.2 Co-efficient of Drag

The graphs were plotted for C_L vs flow time and C_D vs flow time at a velocity of 180m/s. The values are plotted for 245 iterations, the C_L values reaches 8.0199N in first iteration and then drops to the stable value of 8.5366N for further iterations. For C_D the values will reach 27.915N at first iteration and it reaches the values of 1.1466N for rest of the iteration.

The below table shows the Coefficient of Lift and Coefficient of Drag at 60 m/s

Table 5

Type	**C_L**	**C_D**	**C_L/C_D**
Plane wing	0.71082	0.13342	5.3276
Blended 30^0	0.77481	0.14125	5.48538
Blended 60^0	0.7914	0.1405	5.6321
Raked 1	0.7553	0.13799	5.4771
Raked 2	0.7553	0.13838	5.4613
Raked 3	0.757	0.1377	5.4974

The below table shows the Coefficient of Lift and Coefficient of Drag at 180 m/s

Table 6

Type	**C_L**	**C_D**	**C_L/C_D**
Plane wing	7.6853	1.1161	6.8858
Blended 30^0	8.4553	1.1728	7.2094
Blended 60^0	8.5366	1.1466	7.44514
Raked 1	8.2267	1.1455	7.18175
Raked 2	8.2371	1.1498	7.16394
Raked 3	8.2436	1.1441	7.2053

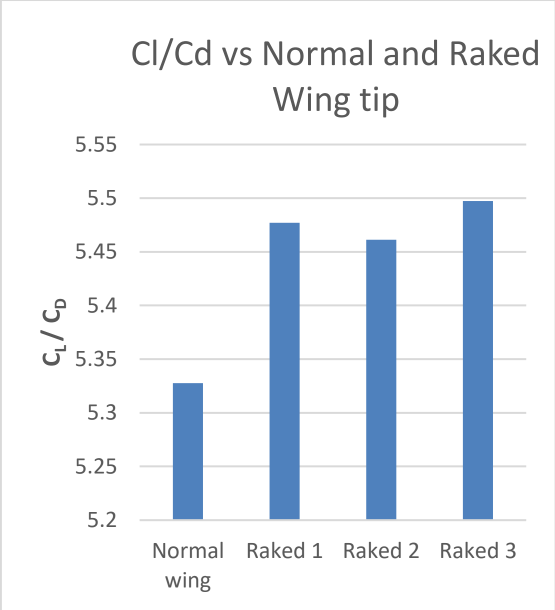

Figure 7.1 C_L/ C_DNormal and Raked Wingtip at60 m/s

The above graph is plotted between the ratio of C_L / $C_D$and Designs of the wings with and without Raked wing tip at 60 m/s. It is observed that the Raked wingtip 3 performed best with high C_L / $C_D$ratio.

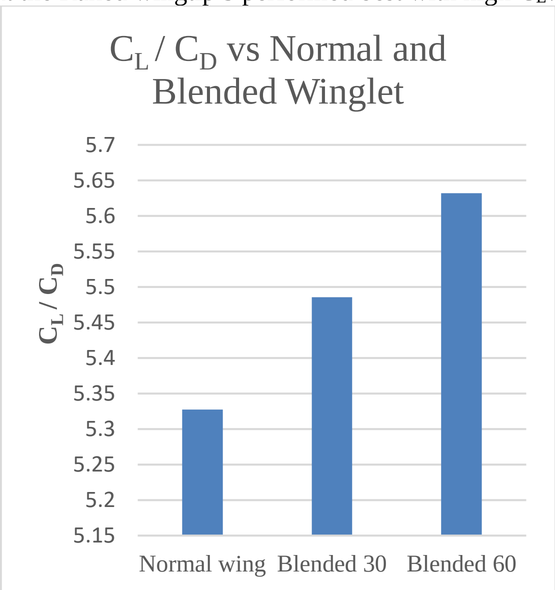

Figure 7.2 C_L / C_DNormal and Blended Winglet at 60 m/s

The above graph is plotted between the ratio of C_L / $C_D$and Designs of the wings with and without Blended winglet at 60 m/s. It is observed that the Blended winglet60^0performed best with high C_L / $C_D$ratio.

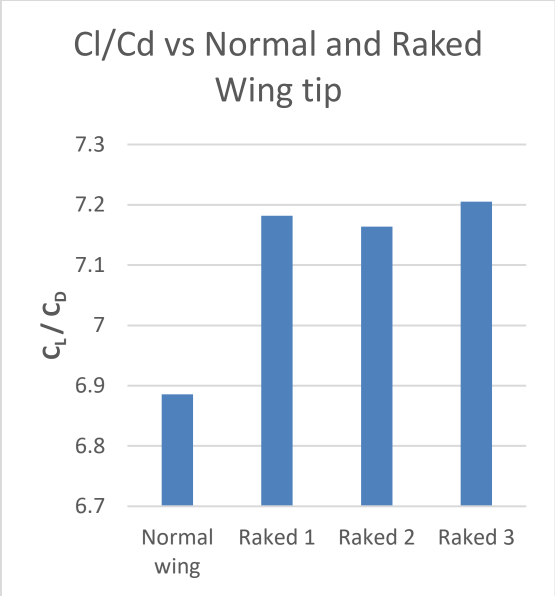

Figure 7.3 C_L / C_D Normal and Raked Wingtip at 180 m/s

The above graph is plotted between the ratio of $C_L / C_D$and Designs of the wings with and without Raked wing tip at 180 m/s. It is observed that the Raked wingtip 3 performed best with high C_L / C_Dratio.

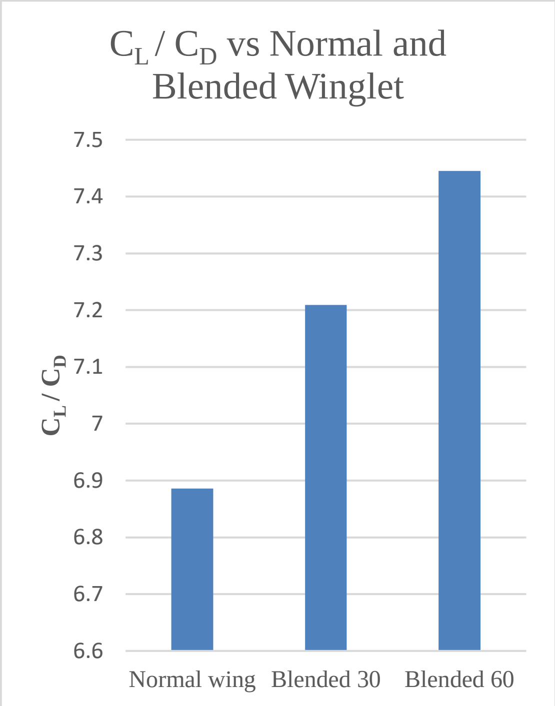

Figure 7.4 C_L / C_D Normal and Blended Winglet at 180 m/s

The above graph is plotted between the ratio of C_L / C_D and Designs of the wings with and without Blended winglet at 180 m/s. It is observed that the Blended winglet 60^0 performed best with high C_L / C_D ratio.

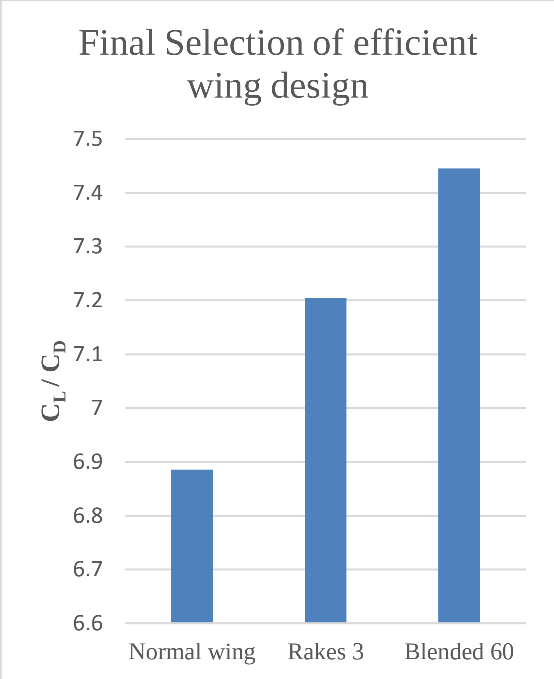

Figure 7.5 Final Result

The above graphs are specially plotted between the ratios of C_L / $C_D$and best of wing designs. In fact, it is observed that the wing with blended winglet at cant angle 60^0 predominantly performed best with pretty much high C_L / C_D ratio.

5. Conclusion

The effect of wingtip devices on wings was investigated in this CFD study by looking at lift and drag coefficient values. The best airfoil NACA 64-215 is selected for wing construction. The importance of the various wingtip devices is shown by the decrease in drag coefficient and increase in lift coefficient. The CFD simulation was performed on a wing with no winglet and two wing designs with winglets. The different types of winglets are"Wing with blended winglet" and "Wing with raked winglet". The simulation was carried out and results of the two separate wing designs with winglets along with wing without winglet were compared. According to the results obtained it concludes that wing with blende Cant angle 60^0 produce more lift and C_L/C_D ratio, when compared to wing with raked 3. The comparison of various types of raked winglets with different racks and wing with blended cant angle 30^0produces less lift and less C_L/C_D ratio when compared with above wing configurations. As a result, the blended winglet with a 60° Cant angle is the most suitable winglet, as it generates the highest C_L/C_D ratio and lift coefficient while also lowering drag coefficient.

7. References

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