CHAPTER 3
Aircrafts Winglets Analysis in CFD

Dr. B. R. Senthil kumar
Nehru Institute of Engineering and Technology, Coimbatore, India

Dr. S. P. Arun kumar
Nehru Institute of Engineering and Technology, Coimbatore, India

Dr. V. M. M. Thilak
Nehru Institute of Engineering and Technology, Coimbatore, India

Mr. S. Balaji
Nehru Institute of Engineering and Technology, Coimbatore, India

ABSTRACT

The main purpose of this project is learning and analysing the aerodynamics performance of Wing and different types of winglets with wings. The aerofoils BAC 449/450/451 designed in solid works and gone through flow simulation in solid works. The best aerodynamically performed aerofoil NACA BAC 449/450/451 in terms of aerodynamic efficiency chosen for wing construction which has dimensions of Boeing 737. The three wing models with different winglets were carried out. Wing with Blended winglet, Ranked winglet and Twin wing simulated to find the aerodynamic efficiency. In order to found more efficient wing with winglets, designs of Blended, Twin and Ranked winglets modified. Blended winglet and Twin winglet with Ranked winglet designed. These 3 wings with winglets studied and simulated in STAR CCM+. As a result of this project it has found that adding the winglet to the wing increase the aerodynamic efficiency of wing in terms of CI/Cd.

Keywords:*aerofoils ,Twin and Ranked winglets,Ranked winglets, Twin wing simulated etc*

INTRODUCTION

A winglet is a device used to improve the efficiency of aircraft by lowering the lift induced drag caused by wingtip vortices. It is a vertical or angled extension at the tips of each wing. Winglets improve efficiency by diffusing the shed wingtip vortex, which in turn reduces the drag due to lift and improves the wing's lift over drag ratio Winglets increase the effective aspect ratio of a wing without adding greatly to the structural stress and hence necessary weight of its structure. Research into winglet technology for commercial aviation was pioneered by Richard Whitcomb in the mid 1970's. Small and nearly vertical fins were installed on a KC- 135A and flights were tested in 1979 and 1980. Whitcomb revealed that in full size aircraft, winglets can provide improvements in efficiency of more than 7%. For airlines, this translates into millions of dollars in fuel costs.Winglets are being incorporated into most new transport aircraft, including business jets, the Boeing 747-400, airliners, and military transport. Many other researchers have investigated their behaviour, designing winglets for commercial and general aviation aircraft as well as for sailplanes. Furthermore, the added friction and interference drag has to be cancelled out by the forward thrust generated by the winglet lift. The upward angle (or cant) of the winglet, its inward or outward angle (or toe), as well as its size and shape are critical for correct performance and are

ISBN: 978-93-5980-498-9, www.aetsjournal.com ― Handbook of research in Modeling of Transportation and Aviation Processes

unique in each application. This study involved obtaining and comparing the aerodynamic characteristics such as drag coefficient, CD, lift coefficient, CL and lift-to-drag ratio, L/D.

THEORY AND BASIC DEFINITIONS:

WINGLET THEORY

Due to circulation about the horseshoe vortex, there exists an induced downwash-which in turn produces induced dag .

VORTEX FORMATIONS

Adding winglets alters the flow at the tip turn decreases the downwash , ultimately reducing drag .

INDUCED DRAG

Induced drag is a force that occurs whenever a moving object redirects the airflow coming at it . it is also called as " drag due to life" as it a source of wing drag .

INDUCED DRAG PHENOMENA

In Aerodynamics, the four main forces which act on aircraft during the flight are Lift, Drag, Thrust and Weight. Drag is one of the most critical phenomena amongst all and is the opposing force of aircraft's forward motion. It could be classified briefly in to parasite drag (not due to lift) and lift induced drag [18]. In a civil transport aircraft, frictional drag and induced drag together contributes more than 80% of the total drag as represented, but the other forms of drag could not be excluded certainly.

Produced by the wing. Normally the vortex wake is produced from the flow pattern due to the difference in velocities at upper and lower surface of an aircraft .It is shown that the veloInduced drag produces kinetic energy which will cause the downward motion perpendicular to the airflow. This downward force could be recognized as the lift vector and this component is regarded as the induced drag. Induced drag differs from the other forms of drag through a phenomenon of converting the dissipated kinetic energy into heat gradually. Vortex wake is a unique feature of induced drag. Dough Mclean has proposed the misinterpretations of the induced drag and the vortex wake cities at the down surface move towards the upper surface and thus it create a circular flow pattern. This flow pattern is responsible for the vortex sheet that produced from the entire span of the wing.

WINGLET

Winglets belong to the class of wingtip devices aimed to reduce induced drag. The winglet contributes to accelerate the airflow at the tip in such a waythat it generates lift and improves the wing loading distribution.

HISTORY OF WINGTIP DEVICES AND WINGLETS

Endplate theory was the first to propose wingtip device and was patented by Fredrick

W. Lanchester, British Aerodynamicist in 1897. Unfortunately, his theory could not reduce the overall drag of aircraft despite reducing the induced drag. The increase in the viscous drag during cruise conditions outruns the reduction in induced drag. In July 1976, Dr. Whitcomb made a research at NASA

Langley research center and developed the concept of winglet technology. According to Whitcomb, winglet could be described as the small wing like vertical structures which extends from the wingtip, aiming at reduction in induced drag when compared to other wing tip devices or extensions. He also claimed in his research that the winglet shows 20% reduction in induced drag when compared to tip extension and also improved lift-to-drag ratio.

In 1994 Aviation Partners Inc. (API) developed an advance design of winglet called blended winglet. Louis B. Gratzer from Seattle has the patent for blended winglet and intention of the winglet is to reduce the interference drag due to sharp edges as seen in the Whitcomb's winglet. Also, Gratzer has the patent for the invention of spiroid-tipped wing in April 7, 1992. Later, "wing grid" concept was developed by La Roche from Switzerland in 1996 and got the patent for his invention. The main purpose of all the above inventions was to decrease the strength of wake vortex and to reduce induced drag.

TYPES OF WINGLETS

After the invention of winglet by whitecomb ,many types of winglets and tip devices were developed by aircraft desingners .

Basically three types of winglets exists,

- BLENDED WINGLET
- RAKED WINGLET
- WINGTIP FENCE
- SPIROID WINGLET

BLENDED WINGLETS (THE REAL WINGLETS):

A blended winglet is attached to the wing with smooth curve instead of a sharp angle and is intended to reduce interference drag at the wing/winglet junction. A sharp interior angle in this region can interact with the boundary layer flow causing a drag inducing vortex, negating some of the benefit of the winglet. The blended winglet is used on business jets and sailplanes, where individual buyer preference is an important marketing aspect.

WINGTIP FENCES:

These are a special variant of winglets that extend both upward and downward from the tip of the wing. Preferred by European plane-maker Airbus, it is featured on their full product range (except the A330/340 family and the future A350).

RAKED WINGTIPS:

These are the most recent winglet variants (they are probably better classified as special wings, though), where the tip of the wing has a higher degree of sweep than the rest of the wing. They are widely referred to as winglets, but they are better described as integrated wingtip extensions as they are (horizontal) additions to the existing wing, than the previously described (near)vertical solutions.

SPIROID WINGLET

Gratzer has developed the spiroid-tipped wing technology and got the patent in 1992. One end of the spiroid tip is attached with forward part of the wing tip and continues to form a spiral loop which ends at the aft portion of the wing tip. Hence it looks oval shaped when viewed from front. Spiroid tipped wing was created to reduce the induced drag and also to reduce the noise effects associated with the tip vortices. API has made their flight test in Dassault Falcon 50 with spiroid tipped wing.

ADVANTAGES CLAIMED ON WINGLETS AND TIP DEVICES :

Ever since the winglet technology has been introduced, the advantages were being published. Dr. Whitcomb has performed an experiment with the winglet in which the winglet shows reduction in induced drag about 20%. In 1977, Heyson made an experiment to study the advantages of Whitcomb's winglet. His results indicate that winglets would reduce the induced drag more than tip extension and will be at its best when it is nearly vertical. Later in 1980, R.T Jones made a research in winglets to determine its effect over the induced drag using Trefftz- plane theory and concluded that the vertical length of the winglet should be twice than the length of horizontal extension in order to have its gain over tip extension.

Aviation Partners Boeing announced that their APB blended winglet has saved more than 2 billion gallons of fuel in 2010. APB also added that the winglets could save 5 billion gallons of fuel by 2014 which also represents the total reduction in carbon emission. Indeed, APB blended winglet on B737 showed increased in range of about 5-7% due to overall reduction in drag. In case of spiroid tipped wing, API has made a flight test on Gulfstream II in 1993 and they achieved more than 10% of fuel efficiency during the cruise conditions2. Raked wingtip is a unique design for Boeing B777 family and it has improved the aircraft's performance by reducing the take-off field length, improved fuel efficiency and good climb performance. Raked wing tip could provide 2% reduction in fuel burn which is compensated by 1.3 million of fuel saving per year and 3.9 million of carbon-di-oxide emission per year3. Sharklets is the recent invention from the Airbus Company for their A320 family. They claimed that sharklets would reduce fuel burn up to 3.4% and this corresponds to 700 tons of carbon emission per aircraft in a year. Airbus also added that A320 could lift off with more weight due to the performance of sharklets4. The research made with spiroid tipped wing indicates that it would disperse the vortex effects with in short span of time and therefore the time for take-off and landing between the aircrafts would be reduced.

LITERATURE SURVEY

Over decades, with so many computational codes and software, such as Fluent, Nastran and Open FOAM, it has become less difficult to predict aerodynamic properties of shapes. However, for efficient analysis in Computational Fluid Dynamics (CFD), one must have a firm understanding of the underlying concepts and theories involved in Fluid Mechanics. It is on this foundation, that we will construct our models and designs.

AERODYNAMIC FORCE AND MOMENT

Air flowing past an airplane, or any other body, must be diverted from its original path; such deflections lead to changes in air speed. Bernoulli's equation shows that the pressure exerted by the air on the airplane is altered from that of the undisturbed stream. Also, the viscosity of the air leads to frictional forces tending to resist the air's flow. As a result of these processes, the airplane experiences an aerodynamic force and moment. It is conventional and convenient to separate aerodynamic force and moment into three components each, as follows.

ISBN: 978-93-5980-498-9, www.aetsjournal.com — Handbook of research in Modeling of Transportation and Aviation Processes

LIFT, L (CZ DIRECTION)

Lift is the component of force acting upward, perpendicular to the direction of flight or of the undisturbed stream. The word "upward" is used in the same sense that the pilot's head is above his feet. It illustrates the meaning in various attitudes of flight. The arrow V represents the direction of flight the arrow L represents the lift acting upward, and the arrow W is the weight of the aircraft and shows the downward vertical. Comparison of (a) and (c) shows that this upward is not fixed relative to the aircraft, while (a), (b), and (d) show that the meaning is not fixed relative to the Earth. As a general rule, if it is remembered that the lift is always a component perpendicular to the flight direction, the exact direction in which the lift acts will be obvious, particularly after reference. This may not apply to certain guided missiles that have no obvious top or bottom, so the exact meaning of "up" must then be defined with care.

DRAG:D

Drag is the component of force acting in the opposite direction to the line of flight, or in the same direction as the motion of the undisturbed stream. It is the force that resists the motion of the aircraft. There is no ambiguity regarding its direction or sense.

CROSSWIND FORCE, Y:

Crosswind is the component of force mutually perpendicular to the lif and the drag that is, in a span wise direction. It is reckoned positive when acting toward the starboard wingtip tright hand to the pilot).

FORCE AND MOMENT COEFFICIENTS

The non dimensional quantity called a force coefficient, F(pF25) (compare, where F is an aerodynamic force and S is an area), is similar to the type often developed and used in aerodynamics. It is not, however, used in precisely this form. In place of v2 it is conventional for incompressible flow to use 12 v2, the dynamic pressure of the free-stream flow. The actual physical area of the body, such as the plan form area of the wing, or the maximum cross- sectional area of a fuselage is usually used for S. Thus the aerodynamic force coefficient is usually defined as follows:

Cf = F/ 1/2 pV2 S

The two most important force coefficients are lift and drag, defined by Lift coefficient C = l

Drag coefficient Co=drag/pV2S

When the body in question is a wing, the area S is almost invariably the plan form area. For the drag of a body such as a fuselage, sphere, or cylinder, S is usually the projected frontal area, the maximum cross-sectional area, or the (volume/2-3). The area used for definition of the lift and drag coefficients of such a body is thus seen to be variable from case to case and therefore needs to be stated for each one.

The impression is sometimes that lift and drag coefficients cannot exceed unity. This is not true; with modern developments some wings can produce lift coefficients of 10 or more based on their plan-area. Aerodynamic moments also can be expressed in the form of non dimensional coefficients.

ISBN: 978-93-5980-498-9, www.aetsjournal.com — Handbook of research in Modeling of Transportation and Aviation Processes

In the case of the pitching moment of a wing, the area is the plan-area S and the length is the mean wing chord. Then the pitching moment coefficient cm is defined by

_

C = M/ 1/2pV2SC

TYPES OF WINGLET

The First winglet designed by Mr. Richard Whitcomb was a small vertical extension at wing tip but for the better preformation lots of modifications made, lots designs created and best designs were selected. Today Lots of winglet design exits such as blended winglets, Raked wingtips, Non planer wingtip, wingtip fence, split scimitar winglets, Hybrid design, etc. some best design which are used mostly because of their better performance are Ranked wingtips, Blended winglets, wingtip fence.

BLENDED WINGLETS

The Blended winglets are the most popular winglets in the aircraft industries, used by Airbus, Embraer, Bombardier, Russian Tupolev, etc. In 1990 the McDonnell Douglas MD-11 aircraft introduced these blended winglets, Boeing came up with a new design, Rather than an abrupt and sharp change up, like the winglets on the 747 400, by curving the gently and raising upwards they could get the increased benefits without needing giant wings. Later Embraer and Airbus also have same design of winglets.

Airbus put the blended winglets on A320 family as Airbus gave the unique design to these winglets they call it Sarkiets'. The winglets inward angle, upward angle, size and shape all depends on its performance and unique performance. Airbus winglets are 2.5 meter in height. This winglets was added on excites A320 and start making now models of A320 and A330 with blandad winglets. The E170/190 of Embraer also have similar design of winglets.

WINGTIP FENCE

This types of winglets extended at the wingtip in both directions upward and downwards. In this types of winglets it already exits the blended winglet and adds another winglet downwards, to increase the surface area and get more efficiency to the existing winglets.

This winglet is the new Boeing "advanced technology winglet". That was manufacture on 737 MAX. According to Boeing "that this winglet will increase fuel efficiency 1.5% greater than what the current blended winglet will provide". As it's mixed with raked winglets it's caled "Dual Feather wingtip design". Today it's Mostly used by Airbus, it design its own winglets. The Airbus 1" used this winglets on A300. Today it giving its performance on A300, A310, A319, A380, etc.

RANKED WINGTIPS

Ranked wingtips are look like just wing span extension but it have higher degree of sweep then the rest of wing. The main advantage of this type of winglets is the simplicity of its design.

That makes it easy to manufacture and add on aircrafts. They are a type of winglets generally known as integrated wingtip extensions as they are horizontal extension on existing wing. This winglets improve the fuel economy, performance of climb and minimise the take off length. It balances the aircraft weight and the cruise efficiency to get better range. Test data of Boeing and NASA shows that "wingtips have been shown to reduce drag by as much as 5.5%, as opposed to improvements of 3.5% to 4.5% from conventional winglets". This winglets use on Boeing 747-8, Boeing 787, Boeing 777, Airbus A350, etc.

REVIEW OF LITERATURE:

The effect of winglets on the aerodynamic performance of a wing has been a subject of detailed research since the 1940s and 50s . more recently , research has been conducted into the proper integration of the winglets combination.

Henderson and holmes., (1989) increased aspect ratio, elliptical loading, and low lift coefficient are the main criteria to be considered for induced drag reduction and classical linearized theory do support this stand. All these criteria have their limitations which cannot be crossed off due to valid design reasons. It is not feasible to allow an increase in aspect ratio and wing span after a certain limit due to structural and weight constraints.

Fredrick lanchester ., (1897) first proposed the endplate wingtip device. This endplate was able to reduce induced drag but was not able to reduce the overall drag. Increase in the viscous drag during cruise out-runs the reduced induced drag. Whitcomb first studied this induced drag vortex generation after his work on supercritical wings and proposed placing vertical wings between the flows to reduce the vortex generation.

Kravchenco., (1996) suggested that modifications in the wingtip can either move the wake vortices away concerning aircraft longitudinal axis or reduce its intensity. Further, he analyzed and concluded that winglets have a higher aerodynamic advantage only up to Mach 1.0, and it may create structural problems due to increased bending moment at the root.

A.Gatto , P. Bourdlin., (2012) An experimental investigation into the real-time flow and control characteristics of a flying wing with articulated winglets is described in this paper. The philosophy of the concept centres around the use of active, in-flight adjustment of each wing's winglet dihedral angle, both as a primary means of aircraft roll control (single winglet actuation) and though smaller equal and simultaneous winglet deflections, tailor and alleviate main wing load.

Shahriar and David W., (2017) An aerostructural perspective on the potential benefits of the wingletted wings in comparison to planar wings of the same projected span.

Raja ,Bino prince D ., (2019) Computational analysis of blended winglet modal performance by varying cant angle .

Shyu ,Jin – cherng , and Jhao – siangJheng .,(2020) Heat transfer enhancement of plate –fin heat sinks with different types of winglet voetex generators.

Wu, Wanyang , and jingjunzhong ., (2021) Experimental investigation of the influence on compressor cascade characteristics at high subsonic speed with pressure surface tip winglets.

METHODOLOGY

WINGLET DESIGN USING ICEM CFD:

Computational Fluid Dynamics (CFD) provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of

- Mathematical modelling (partial differential equations)

- Numerical methods (discretization and solution techniques)

- Software tools (solvers, pre- and post-processing utilities)

CFD TECHNIQUES

CFD enables scientists and engineers to perform 'numerical experiments (ie, computer simulations) in a 'virtual flow laboratory'.

CFD Techniques have emerged with the advent of digital computers. Since then, a large number of numerical methods were developed to solve flow problems using this approach. The basic approach is outlined below.

The purpose of a flow simulation is to find out how the flow behaves in a Even system for a system for a given set of inlet and outlet conditions. These conditions are usually termed boundary conditions.

The basic concept of CFD methods is then to find the values of the flow quantities at a larger number of points in the system. These points are usually Connected together in what is called numerical grid or mesh. The system of differential equation representing the flow is converted, using some procedure, a system of algebraic equation representing the independency of the flow at points and their neighbouring point.

The resulting system of a algebraic equations, which can be linear or Nonlinear, is usually large and requires a digital computer to solve. In essence we end up with the unknowns being flow quantities at the grid points. Solution of the system results in the knowledge of this quantities at the grid points.

If the flow unsteady, either due varying boundaries conditions, or due inherent unsteadiness. The solution procedure is repeated at discrerte time interval to predict the evaluation in time of the variables at the grid points.

With the development of fast and validated numerical procures, and the continuous increase in computer speed and availability of cheat memory larger, and larger problem are being solved using CFD methods at cheaper cost and quicker turn around times. In many design and analysis applications, CFD methods are quickly replacing experimental and analytical methods.

It should be noted that there are certain levels of numerical approximation and assumptions made during the development of CFD models. Hence good understanding of the applicability range and the limitations of a CFD tools is essential to enable the correct use of these tools.

STEPS INVOLVED:

ISBN: 978-93-5980-498-9, www.aetsjournal.com — Handbook of research in Modeling of Transportation and Aviation Processes

The computational steps in this project consist of three stages. The project began from pre-processing stage of geometry setup and grid generation. The geometry of the model was drawn using ICEM CFD.

The grid was generated by ICEM CFD. The second stage was computational simulation by CFD solver using Finite Volume Approach. Finally is the post-processing stage where the aerodynamics characteristics of the winglets were found. Geometry setup was made using wireframe and surface design to draw the 3-dimensional model of winglet. The 3-dimensional unstructured tetrahedral mesh was utilized for computing the flow around the model.

Unstructured mesh is appropriate due to the complexity of the model. The advantages of the unstructured mesh are shorter time consumption in grid generation for complicated geometries and the potential to adapt the grid to improve the accuracy of the computation. After the meshing process, the mesh was examined. The purpose of examining the meshes was to check on the quality of the mesh by observing the skew ness level and abrupt changes in cell Sizes.

Then, the grids generated were developed using size function scheme in ICEM CFD. This will enable finer mesh at the winglet wall and then incrementally increase up to the bullet shaped boundary wall. The numerical simulation by the solver was made after the completion of the mesh generation. The solver formulation, turbulence model Spalart-Allmaras, boundary condition, solution control parameters and material properties were defined.

The initializing and iteration processes stopped after the completion of the computations.

The results obtained were examined and analyzed.

ANALYSIS OF A DESIGN USING ANSYS:

After completing the part design, it was imported by the ansys ICEM CFD for the specific format i.e. IGES (International Graphics Exchange Specification). The part design will meshed using tetrahedral solid elements.

They analysis is carried out using three configurations of winglets name! sharp, cant or blended and normal winglet. Each winglet is analysed using ANSYS ICEM CFX and the design was carried out using ICEM CFD.

The Pre-processing such as meshing is carried out using ANSYS ICEM CFD. The mesh was carried out for the wing with, without and cantor blended winglets.

The winglets are kept at the tip of the wing the dimensions are from a literature and the results are extracted from ICEM CFD post.

DESIGN OF A VARIABLE WINGLETS

Generate enough lift while maintaining the lowest possible drag. Should not stall before wing during low speed flight, and the Geometry driven by aerodynamic characteristics of the airfoil.

AIRFOIL DESIGN OR AIRFOIL SELECTION

The primary function of the wing is to generate lift force. This will be generated by a special wing cross section called airfoil. Wing is a three dimensional component, while the airfoil is two dimensional section. Because of the airfoil section, two other outputs of the airfoil, and consequently the wing, are drag and pitching moment. The wing may have a constant or a non- constant cross-section across the wing.

There are two ways to determine the wing airfoil section:

1. Airfoil design
2. Airfoil selection

The design of the airfoil is a complex and time consuming process and needs expertise in fundamentals of aerodynamics at graduate level. Since the airfoil needs to be verified by testing it in a wind tunnel, it is expensive too. Large aircraft production companies such as Boeing and Airbus have sufficient human experts (aerodynamicists) and budget to design their own airfoil for every aircraft, but small aircraft companies, experimental aircraft producers and homebuilt manufacturers do not afford to design their airfoils.

With the advent of high speed and powerful computers, the design of airfoil is not as hard as thirty years ago. There is currently a couple of aerodynamic software packages (CFD) in the market that can be used to design airfoil for variety of needs. Not only aircraft designers need to design their airfoils, but there other many areas that airfoil needs to be design for their products.

AIRFOIL SELECTION CRITERIA

Selecting an airfoil is a part of the overall wing design. Selection of an airfoil for a wing begins with the clear statement of the flight requirements. For instance, a subsonic flight design requirements are very much different from a supersonic flight design objectives. On the other hand, flight in the transonic region requires a special airfoil that meets Mach divergence requirements. The designer must also consider other requirements such as airworthiness, structural, manufacturability, and cost requirements. In general, the following are the criteria to select an airfoil for a wing with a collection of design requirements:

1. The airfoil with the highest maximum lift coefficient (Cimax).
2. The airfoil with the proper ideal or design lift coefficient (CID).
3. The airfoil with the lowest minimum drag coefficient (Cdmin).
4. The airfoil with the highest lift-to-drag ratio (C/Cdmax).
5. The airfoil with the highest lift curve slope (Clomax).

NACA AIRFOILS

The main focus of this section is how to select a wing airfoil from the available list of NACA airfoils, so this section is dedicated to the introduction of NACA airfoils. One of the most reliable resources and widely used data base is the airfoils that have been developed by NACA (predecessor of NASA) in 1930s and 1940s.

ISBN: 978-93-5980-498-9, www.aetsjournal.com — Handbook of research in Modeling of Transportation and Aviation Processes

THE 6-SERIES NACA AIRFOILS

The four and five-digit airfoil sections where designed simply by using parabola and line. They were not supposed to satisfy major aerodynamic design requirements, such as laminar flow and no flow separation. When it became clear that the four- and five-digit airfoils have not been carefully designed, NACA researchers begin the investigation to develop new series of airfoils that have been driven by design requirements. On the other hands, newly designed faster aircraft require more efficient airfoil sections. Several series of airfoils were designed at that time, but the 6-series were found to be the best. The six series airfoils were designed to maintain laminar flow over a large part of the chord, thus they maintain lower Cdmin compared with four and five-digit airfoils. The 6-series NACA airfoils are designated by five main digits and begin with number 6.

GEOMETRY OF WINGLET

CHORD DISTRIBUTION

If the Chord Distribution is too small then the airfoil will require a large lift coefficient and when it is too big then the high winglet loading causes outboard section of wing to stall prematurely.

The Elliptical plan form will help with load distribution over a large range of flight regimes.

WINGLET HEIGHT

The Height of the Winglet is determined by the optimal induced drag and profile drag relationship.

TWIST/SWEEP

The Twist /Sweep angles have similar effects on the winglet and They Tailor the load distribution.

TOE ANGLE

It controls overall loading on winglet, Effects the load distribution on main wing and it is only optimum for one flight condition

WINGLET SPECIFICATIONS AND DESIGN

BLENDED WINGLET

Aircraft Manufacture Companies does not share actual dimensions of their aircrafts but still they share few dimensions. Boeing 737 winglet height is 2.4m (for my project it is 2.4*14= 33.6mm) [34]. The aerofoil model with wing shown below in.

RAKED WINGLET

This winglet is 21 long .

TWIN WINGLET

ISBN: 978-93-5980-498-9, www.aetsjournal.com — Handbook of research in Modeling of Transportation and Aviation Processes

This winglet total height is 41.63 mm.

MESHING AND PRE-PROCESSING

The meshing / Discretization are carried out for winglet cases. Unstructured tetra elements are selected for these computations .

The mesh generated after giving all necessary parameters and as on output results are below.

1196851 cells , 8370820 faces , 7198239 verts. The image below shows fine mesh on wing domain and on wing itself . it can be seen that all the edges and surface of wing come up with smooth mesh. this mesh is acceptable for study.

RESULTS AND DISCUSSIONS

Post processing of the results is carried out. contours of pressure and velocity of both the simulations are generated. The following shows the pressure counters of blended, raked and twin winglets.

- Blended Winglet
- Raked Winglet
- Twin Winglet
- Blended Winglet Drag And Lift
- Raked Winglet Drag And Lift
- Twin Winglet Drag And Lift

CONCLUSION AND FUTURE WORK

The aim of this project was to CFD analyse the wing without winglet and the increase aerodynamic efficiency after attaching the winglet at wingtip, also to find the wing design with winglet with better efficiency. The rising cost of fuel, operating cost and increasing CO_2 in atmosphere is the reason aircraft industry started researching to get efficient aircraft designs. The aircraft industries found some design modification in wing design by adding winglets to reduce the drag and air vortex but researcher will always continue to find better outcomes. In this research it was ascertained that adding the winglets to the wingtip increase the aerodynamic efficiency in terms of CI/Cd. Furthermore, the reduction in air vortex behind the wing, was proven in this study by the adding a winglet to the wingtip.The research on aerodynamics, aerofoil geometry, the wing design, wingtip vortex, winglets designs and the construction of wing with winglet conducted to meet the project aims. The designing process begins with the 2D simulation of different aerofoils(BAC 449/ 450/ 451) on different AOA. The simulation results shows that BAC 451 has the high value of CI/Cd then others so used for construction of wings. The wing without winglet and 3 wings with different winglets were also designed in solid works.

The CFD simulation carried out for wing without winglet and 3 wing designs with different winglets. The 3 designs are WING WITH BLENDED WINGLET, WING WITH WING TIP FENCE, and WING WITH RANKED WONGLET. The simulation results of all 3 different wing designs with winglets were conducted and compared to find the best performed winglet design.According to results the wing with Ranked winglet was found with higher efficiency than others wing with winglets designs but still leaves a room for further improvements in this design. In order to increase the aerodynamic efficiency of wing Ranked winglet and Blended winglet has modified, 3 wing designs with winglets created for further study. 3 wing with Blended winglet and 5 models of Ranked winglet designed in solid works and CFD analysis carried out in STAR-CCM+. In the results of CFD analysis of wing designs it was learned that wing with Blended winglet 2 has the maximum aerodynamic efficiency in terms of CV/Cd in this study. By using this winglet the efficiency of wing has increase by 5.57%. According to this study it was also found that adding the winglet to the wing improves aircraft performance which will not only make it sustainable in terms of carbon reductions but also fuel efficient.

The following activities intend doing after completion of this project dissertation:

- Creating new winglet designs by improving the geometry of winglets.
- Design winglets with different aerofoil and do CFD analysis.
- Analysis of wing with wingtip devices such as wing grid, serrated wingtips etc.
- Investigation of models with much more accurate operating parameters such as temperature, velocity, pressure.
- Investigate the overall efficiency of aircraft before and after using the new winglet designs.

REFERENCES

[1] Premkumar, P et.al . (2011). Performance Analysis of Winglets Using CFD Simulation. Altair Technology conference. Coimbatore

[2] CFD Analysis of Winglets at Low Subsonic Flow. (2015). Proceedings of the World Congress on Engineering 2011, Vol I(WCE 2011), pp.1-5.

[3] Houghton, E. and Carpenter, P. (2003). Aerodynamics for engineering students. Oxford: Butterworth-Heinemann.

[4] Esru.strath.ac.uk, (2015). Flexible Moorings For Marine Turbine[Accessed 20 Sep. 2015].

[5] Airframe and powerplant mechanics. (2015). Washington DC: U.S. Department of Transportation Federal Aviation Administration, pp.30-31

[6] Slideshare.net, (2015). EASA PART-66 MODULE 8.2: AERODYNAMICS. [Accessed 21 Sep. 2015].

[7] Adg.stanford.edu, (2015). Wing Design Parameters [Accessed 21 Sep. 2015].

[8] Adg.stanford.edu, (2015). Wing Design Parameters [Accessed 21 Sep. 2015].

[9] Airframe and powerplant mechanics. (2015). Washington DC: U.S. Department of Transportation Federal Aviation Administration, pp.32-34.

[10] Carpenter. P. (2015). Learn How Airplanes Fly [Accessed 15 Sep. 2015].

[11] Airplanes-aircraft.knoji.com, (2015). Winglets: A Novel Design with a Purpose. [Accessed 25 Nov. 2015].

12] Wonderwhizkids.com, (2015). wonderwhizkids.com - Flight of migratory birds. [Accessed 18 Sep. 2015].