DESIGN AND ANALYSIS OF WINGLETS WITH MODIFIED TIP TO ENHANCE PERFORMANCE BY REDUCING DRAG

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ABSTRACT:

Winglets being a small structure play an important role in reducing the induced drag in Aircraft . Many types of winglets have been designed and their significance in reducing the Drag is published. One of the main objectives of this master thesis work is to study about the winglet design and about their contribution in reducing induced drag. A brief overview of wing tip devices and their performance from the manufacturers as well as from airliner's point of view are discussed. Moreover, the role of winglet in reducing the drag of commercial civil jet aircraft is studied and the percentage of drag reduction is calculated by a conceptual approach . A320 specifications are taken to perform induced drag reduction calculation with and without winglets. Indeed, the total drag count reduced with the help of winglets accounts for additional payload which will be an advantage for the aircraft operator.

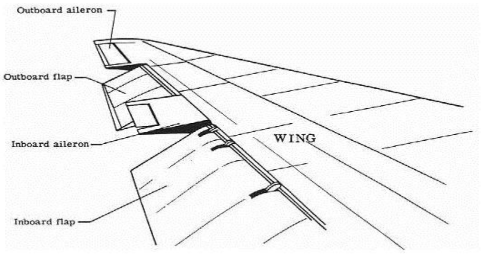
Reducing the process time in design is one of the important criteria for any field and hence automation with help of CAD tools is very significant in reducing time. This study also aims at developing an automated model for different types of winglets and wing tip devices with the help of CAD technology focused on reducing design time during the initial design process . Knowledge based approach is used in this work and all the models are parameterized so e ach model could be varied with associated parameters. The generic model created would take different shapes and switches between different types of wing tip devices as per the user's requirement with the help of available parameters. Knowledge Pattern (KP) approach is used to develop the automation process. User Defined Features (UDFs) are created for each type of winglet and tip devices. CATIA V5 R18 software is used to develop the models of winglets and tip devices.

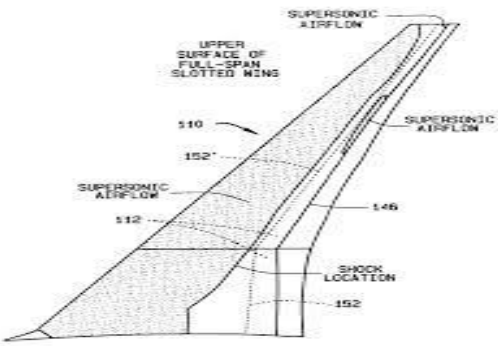
INTRODUCTION

WING:

A wing is a type of fin with a surface that produces aerodynamic force for flight or propulsion through the atmosphere, or through another gaseous or liquid fluid. As such, wings have an airfoil shape, a streamlined cross-sectional shape producing a useful lift to drag ratio.

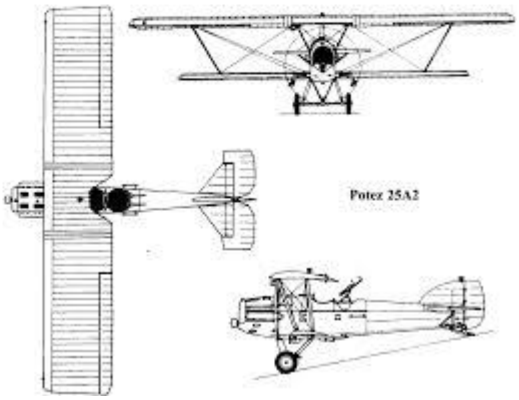
The word "wing" from the Old Norse vængr for many centuries referred mainly to the foremost limbs of birds (in addition to the architectural aisle.) But in recent centuries the word's meaning has extended to include lift producing appendages of insects, bats, pterosaurs, boomerangs, some sail boats and aircraft, or the inverted airfoil on a race car that generates a downward force to increase traction.



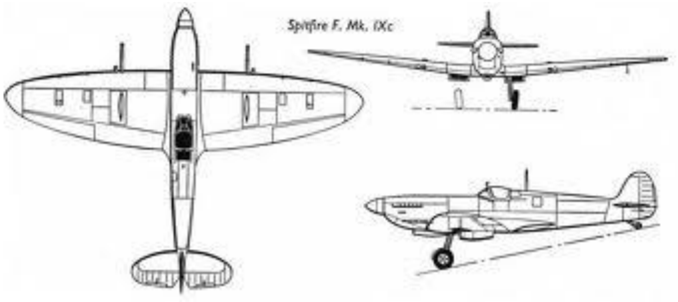


A wing's aerodynamic quality is expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift.

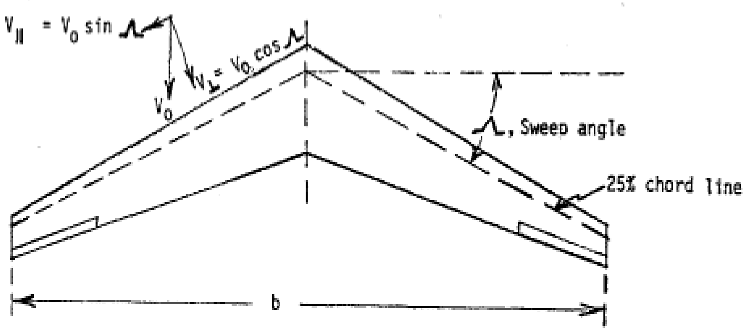
TYPES OF WING:



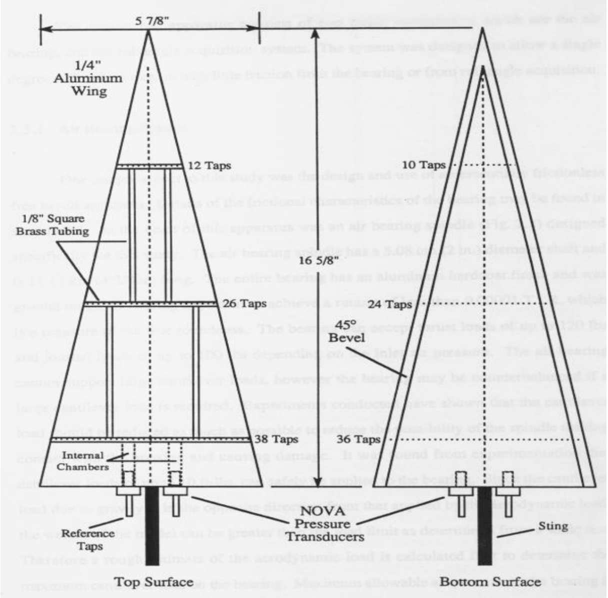
Rectangular Wing

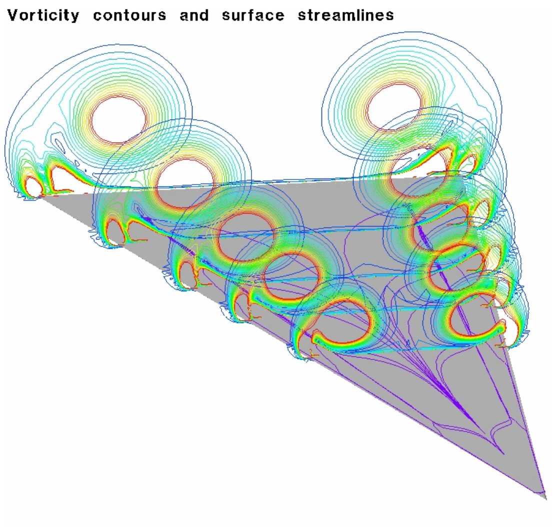


Elliptical Wing:



Swept Wing:





Delta Wing:

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.

The Benefits of Wingtip Devices

From an aerodynamicist's point of view, the motivation behind all wingtip devices is to reduce induced drag. Beyond that, as Whitcomb showed, the designer's job is to configure the device so as to minimize the offsetting penalties, so that a net performance improvement is realized. For any particular airplane and tip device, the performance-improvement can be measured relative to the same airplane with no tip device. The positive factors and offsetting factors that contribute to the performance improvement can be listed as follows:

Positive factors:

- Induced drag is reduced at takeoff and cruise.

- Shock drag is sometimes reduced a little at cruise due to the change in spanload produced by the device.

Offsetting factors:

- Profile drag is increased due to:

– Increased wetted area.

– Junction flows, high sectional loadings, etc.

- Weight is increased due to:

– The weight of the device itself.

– The weight of attachment fittings.

– Increases in the weight of the existing wing structure due to increases in static loads and to meet flutter and fatigue requirements.

A net performance improvement is satisfying to an engineer, but for an airplane manufacturer or operator the objective is to realize the kind of bottom-line benefits that translate into dollars. Here is a list of the potential bottom-line benefits of tip devices, in rough order of importance, and some offsetting factors:

Benefits:

- Improved performance:

– Reduced fuel burn.

– Increased maximum range.

– Reduced takeoff field length due to improved second segment climb.

– Increased cruise altitude due to improved buffet boundary.

– Increased cruise speed due to modest increase in MDD

– Reduced takeoff noise.

- Meet gate clearance with minimal performance penalty.

- Appearance and product differentiation.

Offsetting factors:

- Increased cost (development, recurring, and purchase).

- Increased development risk.

Another possible benefit that has sometimes been put forward is that tip devices can reduce the strength of the vortex wake, with the implication that this could lead improved safety or reduced separation distances on landing approach or takeoff. This one is not included on our list because the reduction in vortex strength is typically very small, and the resulting benefit is insignificant.

The main positive factor that makes the benefits possible is the reduction of induced drag. In the next section we discuss the physics of induced-drag reduction and the implications for the configuration of effective wingtip devices.

The vortex wake

A distinctive feature of the wing-induced flowfield that is prominent in discussions of induced drag, and that plays a role in the quantitative theory, is the trailing vortex wake. The nature of the vortex wake and its role in induced drag have been a source of some serious misunderstandings, and these erroneous ideas have resulted in numerous proposals for tip-device concepts that cannot work as their proponents claim. We therefore take care in the following discussion to develop a correct understanding of the vortex wake and its role and to point out where some of the erroneous concepts went wrong.

Figure 3.1. Velocities in a crossflow plane behind a lifting wing

The vortex wake starts as a vortex sheet shed from the trailing edge of the wing as a byproduct of producing the flow pattern shown in Figure 3.1. To understand the origin of the vortex sheet, look at the velocity vectors immediately above and below the wing in Figure 3.1. Note that the vertical components of these velocities are the same above and below the wing, but that the horizontal (spanwise) components undergo a "jump," from the outboard direction below the wing to the inboard direction above the wing. It is this jump in the spanwise velocity component that constitutes the vortex sheet that ends up streaming back from the wing trailing edge. The vortex sheet is a necessary part of the flowfield because the conservation laws of fluid mechanics dictate that the wing cannot produce the general flow pattern of Figure 3.1 without also producing the jump in spanwise velocity. On an intuitive level, the spanwise-velocity jump can be understood as being a result of the tendency of air to flow away from the high pressure under the wing toward the low pressure above the wing. The wing itself presents an obstacle to this motion and deflects it in the spanwise direction.

COMPUTER AIDED DESIGN:

Aircraft design being a complex process has many phases in which Computer Aided Design (CAD) plays a significant role. Many aircraft manufacturers such as Boeing, Dassault, and Airbus have been adopting the CAD software tool like CATIA in order to minimize the lead time and to avoid prolonged duration in design process. CAD combined with Knowledge based engineering (KBE) aimed at reducing time the taken for design process in case of repetition . Studies have been done on developing parameterized CAD models focusing to optimize the given model with less duration of time . D operator and K operator were the two approaches developed with CAE tools for making repetitive process. VB script is associated with D operator, whereas Knowledge Pattern (KP) developed based on C++ programming language, is under the K operator approach .

KP has been implemented in Dassault systems software CATIA V5 R16. One of the main disadvantages in VB script for dynamic instantiation of the models is longer time consumption for scripting. Studies revealed that automation for creating models and patterns dynamically were done based on Knowledge Pattern script where the time consumed for pattern creation and scripting were much lesser than VB approach.

Design Requirements

Because a winglet does not operate exactly as a wing does, the performance benefits if the airfoil used is designed specifically for that purpose. To do this, it is necessary to fully determine the operational conditions of the winglet and how they relate to those of the wing. Because the principal benefit of a winglet is in climb, he airfoil performance at low flight speeds is of primary importance. Thus, the airfoil must generate the maximum lift coefficient required by the winglet as the aircraft main wing approaches stall. Likewise, low-drag performance over the entire operating range is mportant, but must be considered in conjunction with other constraints.

As the profile drag increases with velocity squared, a large drag coefficient at low lift coefficients would severely penalize the aircraft performance at higher flight speeds. This drives the low lift-coefficient portion of the airfoil drag polar. The degree to which these considerations influence the overall performance is difficult to ascertain without considering the entire flight profile of the sailplane. To do this, a method of sailplane performance has been developed that can be used to determine how much of a gain at low speed is needed to offset a loss at highspeed.

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

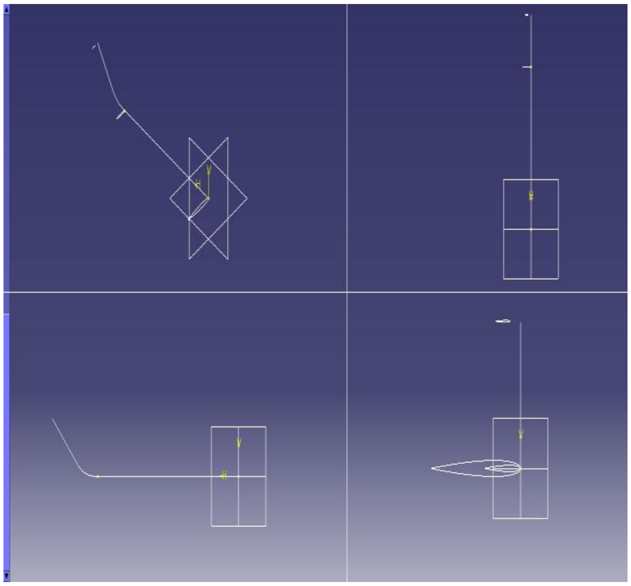
Computer-aided design is used in many fields. Its use in designing electronic systems is known as Electronic Design Automation, or EDA. In mechanical design it is known as Mechanical Design Automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

CATIA V5 R16

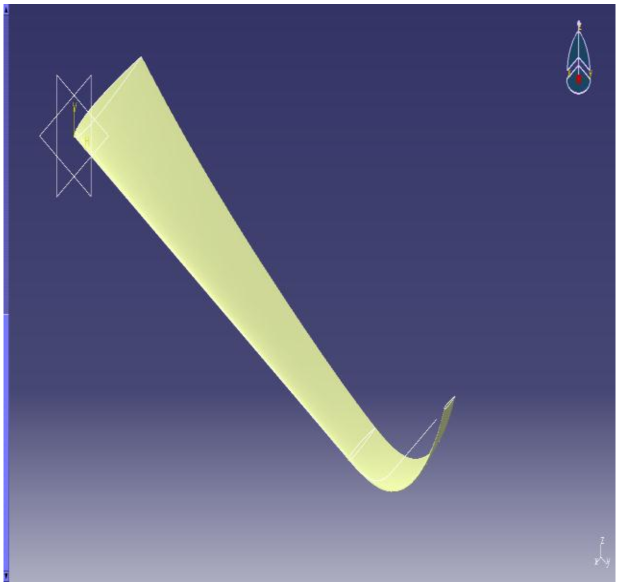
(Computer Aided Three Dimensional Interactive Application)

The 3D CAD system CATIA V5 was introduced in 1999 by Dassault Systems. Replacing CATIA V4, it represented a completely new design tool showing fundamental differences to its predecessor.
The user interface, now featuring MS Windows layout, allows an easy integration of common software packages such as MS Office, several graphic programs or SAP-R3 products (depending on the IT environment) and others.
CATIA (Computer Aided Three-dimensional Interactive Application) (in English usually pronounced /kəˈtiə/) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systèmes. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systèmes product lifecycle management software suite.

CATIA competes in the high-end CAD/CAM/CAE market with Creo Elements/Pro and NX (Unigraphics).

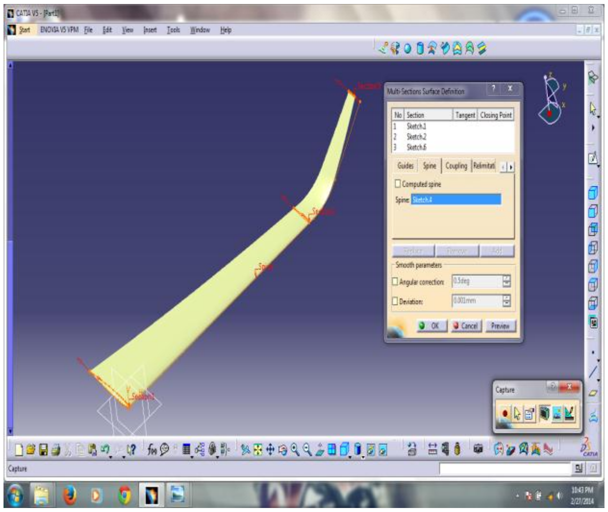


After the airfoil in the curve is created the" multisection" command is being used to connect the three airfoil to create the following design.



The above picture only shows the design without spline

The picture with spline and sweep of angle 115 degree's is as follows.



No	Section	Tangent	Closing Point
1	Sketch.1		
2	Sketch.2		
3	Sketch.6		

☐ Computed spine
Spine: Sketch.4
Smooth parameters
☐ Angular correction: 0.5deg
☐ Deviation: 0.001mm

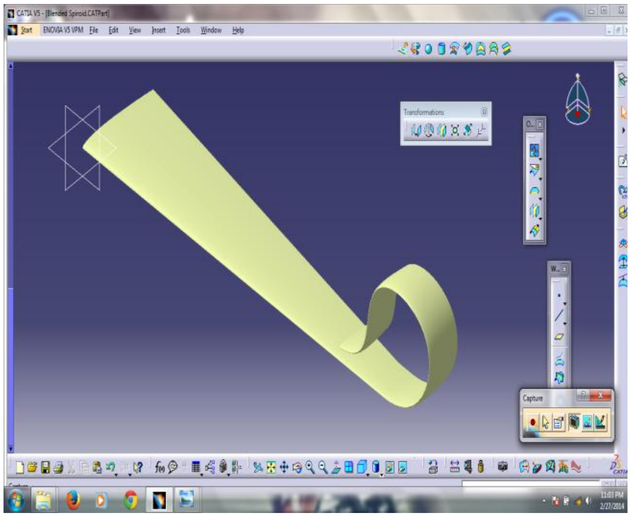
Now this wireframe is subjected to create a solid model. So to create a solid model of above wireframe design the design is to be thoroughly checked for an unclosed surface, because the "catia" won't allow the open surface to create a solid body.

So the design is checked for any open surfaces . So if there are any we use "spline command" to close the structure.

Here the different airfoils are selected and created as one domain using "multisection"

After the airfoil in the curve is created the" multisection" command is being used to connect the three airfoil to create the following design.

The whole angle is almost 360 degree but it is arranged according to our assumptions.



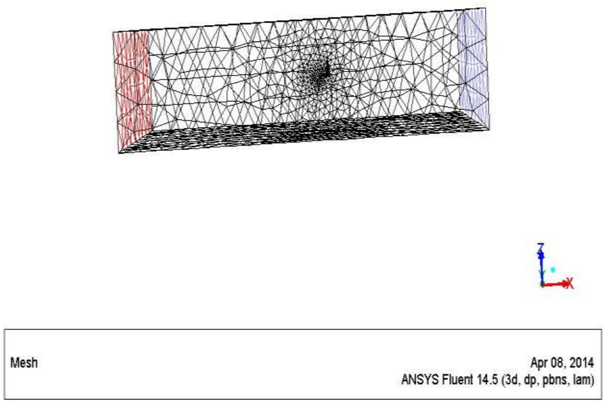
MESHING THE WINGLETS using ANSYS 14.0 WORKBENCH

ANSYS, Inc. is an engineering simulation software (computer-aided engineering, or CAE) developer that is headquartered south of Pittsburgh in the Southpointe business park in Cecil Township, Pennsylvania, United States.

ANSYS was listed on the NASDAQ stock exchange in 1996. In late 2011, ANSYS received the highest possible score on its SmartSelect Composite Ratings according to Investor's Business Daily. The organization reinvests 15 percent of its revenues each year into research to continually refine the software.

ANSYS 14.0 delivers innovative, dramatic simulation technology advances in every major physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. These advancements alone represent a major step ahead on the path forward in Simulation Driven Product Development. But ANSYS has reached even further by delivering all this technology in an innovative simulation framework ,ANSYS Workbench 2.0.The ANSYS Workbench environment is the glue that binds the simulation process; this has not changed with version 2.0.

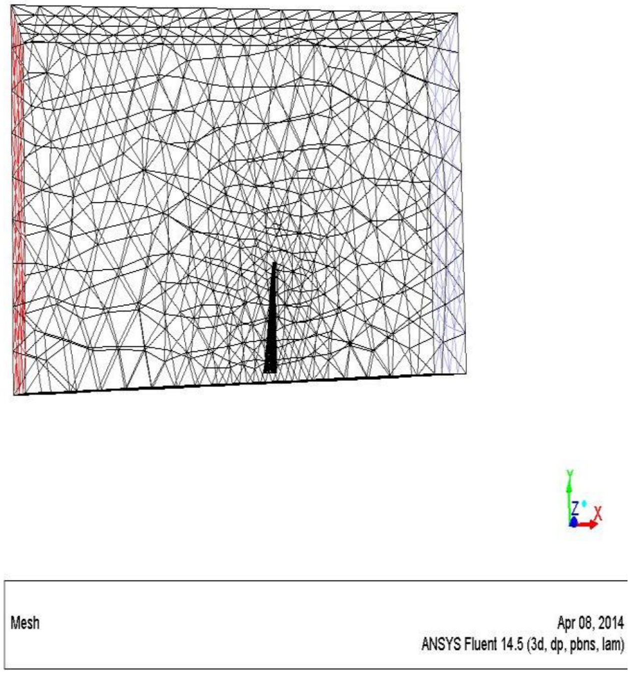
In the original ANSYS Workbench, the user interacted with the analysis as a whole using the platform's project page: launching the various applications and tracking the resulting files employed in the process of creating an analysis. Tight integration between the component application yielded unprecedented ease of use for setup and solution of even complex multiphysics simulations. In ANSYS 14.0, while the core applications may seem familiar, they are bound together via the innovative project page that introduces the concept of the project schematic.



Mesh-generate

After this export the file to fluent.

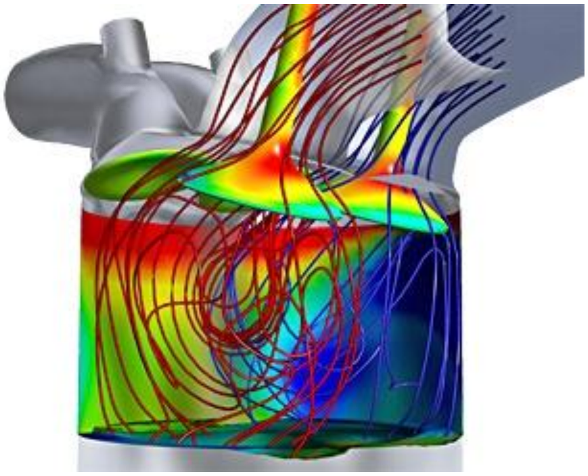
The mesh file looks like the figure below



ANALYSIS USING ANSYS FLUENT

ANSYS Fluent software contains the broad physical modeling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Special models that give the software the ability to model in-cylinder combustion, aeroacoustics, turbomachinery, and multiphase systems have served to broaden its reach.

View larger imageInternal combustion engine modeled using ANSYS Fluent



Today, thousands of companies throughout the world benefit from the use of ANSYS Fluent software as an integral part of the design and optimization phases of their product development. Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability. User-defined functions allow the implementation of new user models and the extensive customization of existing ones. The interactive solver setup, solution and post-processing capabilities of ANSYS Fluent make it easy to pause a calculation, examine results with integrated post-processing, change any setting, and then continue the calculation within a single application. Case and data files can be read into ANSYS CFD-Post for further analysis with advanced post-processing tools and side-by-side comparison of different cases.

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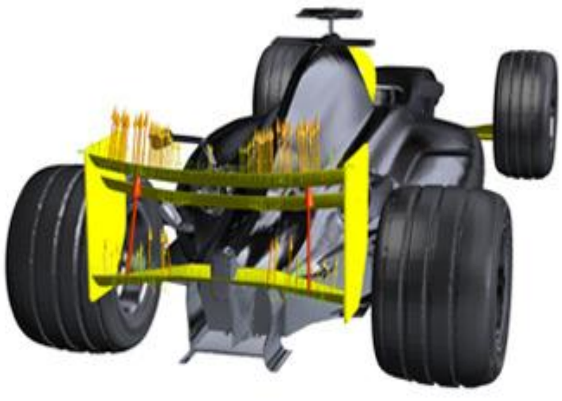
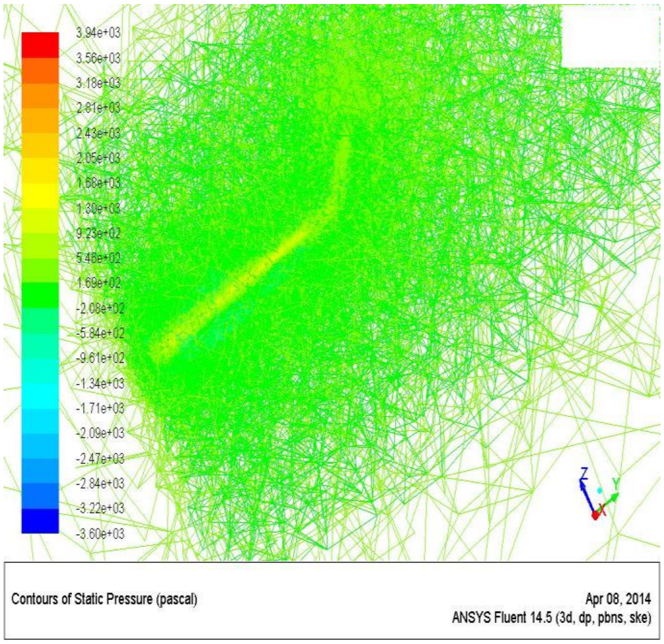


FIG :ANSYS Fluent adjoint solver indicates the necessary shape changes to ensure maximum down force for a race car

The combination of these benefits with the extensive range of physical modeling capabilities and the fast, accurate CFD results that ANSYS Fluent software has to offer results in one of the most comprehensive software packages for CFD modeling available in the world today. A native two-way connection to ANSYS structural mechanics products allows capture of even the most complex fluid–structure interaction (FSI) problems in the same easy-to-use environment, saving the need to purchase, administer or run third-party coupling software. Other multiphysics connections include electromagnetic–fluid coupling.

The flow over a 3d blended winglet after 1000 iterations is as follows



RESULTS AND CONCLUSIONS:

Cases Wth Blended Winglet And Spiroid Winglet :

As seen in Fig below the largest amount of turbulence in the flow is associated with the winglet. The clean wing also produces a turbulent flow as air flows over the wingtips. The spiroid wingtip exhibits the least amount of disruption aft of the tip, due to its more aerodynamic design.

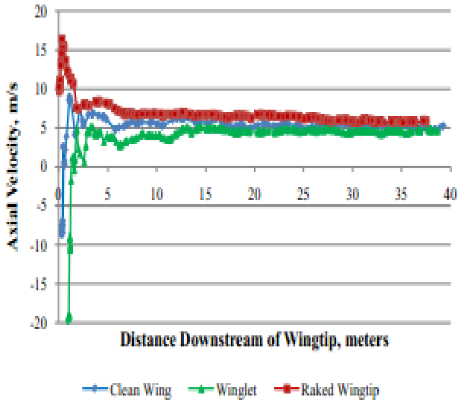


FIG: TURBULENT FLOW ASSOCIATED WITH WINGLETS

The vorticity of the vortex wake for each wingtip is plotted in Fig. below. The range of the plot extends from the wingtip of each wing to the boundary of the flow domain, in the direction of the freestream. Noticeable in Fig below is the dramatic reduction of vorticity in the wake region associated with the spiroid wingtip model. The plot indicates that the vorticity associated with the clean wing and the wing with winglets configurations share a similar flow pattern. However, upon closer inspection of the plot the vorticity magnitude in the vortex wake of the clean wing is

more erratic and turbulent than for the wing with winglets. As illustrated in the previous vector and contour plots, the wing with winglets configuration produces strong wingtip vortices, however they are less turbulent and more concentrated than the clean wing configuration.

The graph is shown below.

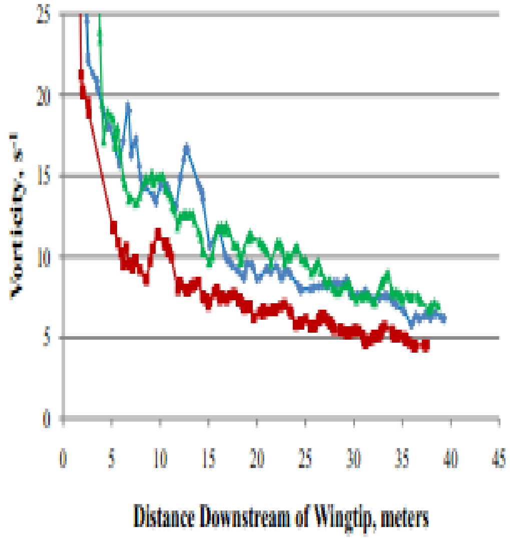
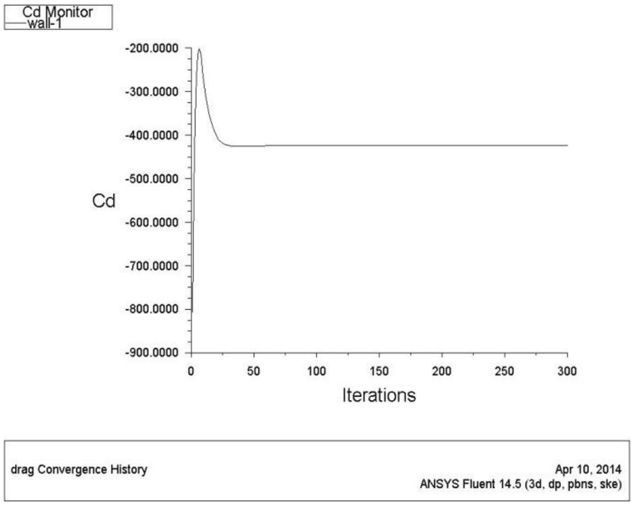


FIG: REDUCTION IN VORTICITY

GRAPH OF DRAG CONVERGENT (Cd VS ITERATIONS):



These are the two graphs below for the blended winglet drag and lift respectively.

Now observing this graph, at the beginning as we can see the drag is far more greater than any in the field represented.

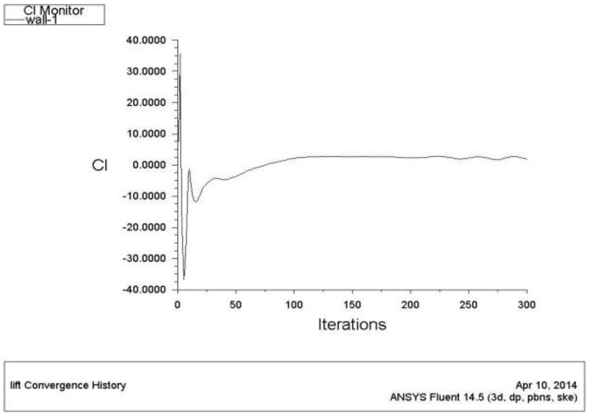
At the beginning of the flow of velocity 133km/sec the drag gradually increases to the critical point and later the drag on the surface of the body, decreases gradually until it reaches a certain point where the drag is standard until the converging of the structure.we can conclude that from drag graph the reduction in drag gradually.

By reducing the drag we can increase the lift and we get the more thrust and this will help the aircraft to reduce take off distance and increase the fuel efficiency.

By reducing the drag we can increase the lift and we get the more thrust this will help the aircraft to reduce take off distance and increase the fuel efficiency.

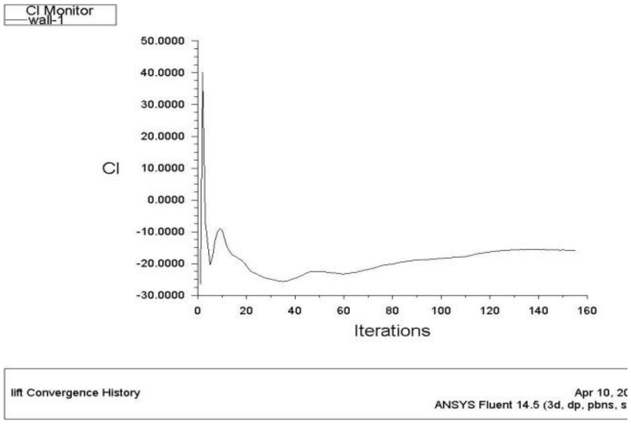
The lift graph below explains how the lift is generated is far more efficient than the other wings with no wingtip devices.

Hence the lift convergence graph explains as iterations increases the performance against drag.



These are the results of spiroid winglet this also reduce the induce drag this will help in reduce the take off distance, weaks and de-strength the vertices.

When we observe the both blended and spiroid winglets blended winglet reduce the induced drag more effectively then the spiroid winglet



Conclusion/Recommendations/ Assumptions :

The present study serves as a preliminary investigation into the aerodynamic effects of different wingtip configurations on the wingtip vortices generated as a result of the induced drag on a wing. In addition, the advantages and disadvantages of 3-D finite wings with winglets and spiroid wingtip wing configurations were investigated. The results presented in this study reveal two methods for reducing wingtip vortices and, consequently, the induced drag on a 3-D wing.

This study has shown that clean wing configurations, i.e., wings without wingtip devices, produce the highest vorticity magnitudes when compared to wing configurations that employ either winglets or spiroid wingtip designs. The vortex wake generated by clean wing configurations reduce the aspect ratio of the wing, thereby increasing the induced drag on the wing. The winglet design employed in this study demonstrate the potential to produce a component of force in the thrust direction of the aircraft by concentrating the otherwise turbulent and chaotic vortex flow behind the wingtips into a more energy-efficient flow, thereby counteracting the drag on the wing.

Alternatively, spiroid wingtips reduce the overall magnitude of the tip vortices, thereby reducing the induced drag on the wing. The streamline design of the spiroid wingtips provide less resistance to the flow over the wingtips and, in this way, conserve the energy of the flow. The results of this preliminary study suggest that wings designed with winglets or spiroid wingtips can indeed reduce the induced drag on a wing during cruise conditions. This reduction of the induced drag on an aircraft's wing offer advantages in terms of an aircraft's performance including improved fuel efficiency, increased range, and reduced wing loading.

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