

DESIGN AND FABRICATION OF SWEPTBACK WING WITH CORRUGATED WINGLET

submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with grade "A++" by NAAC.

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **ALLEN JOEL. J (40260002)** and **MUKILAN. N (40260017)** who carried out the project entitled "**Design and Fabrication of sweptback wing with corrugated winglets**" under my supervision from November 2023 to April 2024.


Internal Guide

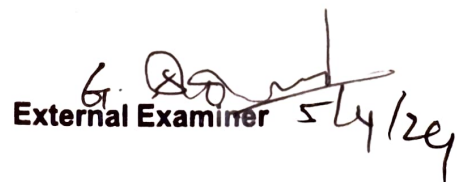
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ABSTRACT

The design and fabrication of sweptback wings with corrugated winglets represent an innovative approach to enhance the aerodynamic performance of aircraft. This research project explores the integration of sweptback wings with corrugated winglets to improve overall efficiency, reduce drag, and increase the aircraft's fuel economy. The aim of this study is to demonstrate the feasibility and benefits of this novel aerodynamic configuration. The project begins with a comprehensive literature review, which delves into the principles of aerodynamics, winglet design, and the advantages of corrugated structures in enhancing lift and reducing drag. This theoretical foundation serves as a basis for the subsequent design and analysis phases.

In the design phase, detailed aerodynamic simulations are conducted to optimize the wing's sweep angle and winglet corrugation patterns. Computational Fluid Dynamics (CFD) simulations are employed to assess the aerodynamic performance of the new configuration in various flight conditions. The results show that the integration of corrugated winglets with sweptback wings can significantly reduce induced drag and improve lift-to-drag ratios. The fabrication phase of the project involves manufacturing a scaled-down model of the aircraft wing with the designed configuration using advanced materials and manufacturing techniques. This model is used to validate the CFD simulations and assess the practicality of constructing such wings for full-scale aircraft.

The findings of this research demonstrate that the incorporation of corrugated winglets with sweptback wings can yield substantial improvements in aerodynamic performance, leading to increased fuel efficiency and reduced emissions. Moreover, this innovative design approach offers potential benefits for both commercial and military aircraft, where reducing operational costs and environmental impact are paramount.

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LIST OF SYMBOLS & ABBREVIATION

SYMBOLS	DESCRIPTION
Cl	Coefficient of Lift
Cd	Coefficient of Drag
Cor	Corrugated
ρ	Density of Air
A	Swept Area
V	Wind Velocity
L	Lift
AR	Aspect Ratio
AOA	Angle of Attack
Cp	Coefficient of Pressure
Ps	Static Pressure

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The design of sweptback wings with corrugated winglets is a multifaceted process, encompassing aerodynamic analysis, structural considerations, and advanced manufacturing techniques. It commences with the establishment of precise requirements and objectives, tailored to the intended purpose of the aircraft and regulatory standards. Extensive aerodynamic analysis, utilizing tools like Computational Fluid Dynamics (CFD), guides the determination of optimal wing sweep angles and corrugated winglet designs.

The wing's planform, including span, aspect ratio, and taper ratio, is then crafted to meet performance goals while adhering to structural integrity criteria. Simultaneously, the design of corrugated winglets involves optimizing the corrugation pattern, size, and shape, carefully considering both aerodynamic efficiency and structural resilience. Effective integration of winglets into the main wing structure is essential for achieving seamless aerodynamic transitions and structural robustness.

The selection of suitable materials, possibly advanced composites, and manufacturing techniques follows, aimed at optimizing weight, strength, and durability. Prototyping, testing, and validation of the scaled-down model ensure the design's accuracy and performance, with necessary refinements based on test results. The design process culminates in full-scale implementation, compliance with aviation regulations, and ongoing improvements to enhance aerodynamic efficiency, fuel economy, and overall aircraft performance.

The fabrication phase of the project entails the construction of a scaled-down model of the aircraft wing configured according to the design, utilizing advanced materials and manufacturing techniques. This model is utilized to validate the CFD simulations and evaluate the feasibility of implementing such wings in full-scale aircraft.

1.2 SELECTION OF WINGS

Choosing the appropriate wing for an aircraft involves a comprehensive evaluation of multiple factors such as the intended mission, performance needs, aerodynamic properties, structural requirements, and feasibility of manufacturing.

- **Mission Profile:** Determine the primary purpose of the aircraft, whether it's commercial transport, military operations, general aviation, aerobatics, or specialized missions like reconnaissance or air ambulance. Tailor the wing design accordingly, taking into account factors such as range, payload capacity, speed, and maneuverability pertinent to the mission.
- **Aerodynamic Performance:** Assess the aerodynamic performance criteria, encompassing lift-to-drag ratio, stall characteristics, stability, and control. Select a wing design that optimizes performance based on desired cruise speed, climb rate, and maneuvering capabilities under diverse conditions.
- **Aspect Ratio:** Aspect ratio, denoting the ratio of wingspan to mean chord, significantly influences aerodynamic efficiency and lift distribution. Opt for high aspect ratio wings for enhanced efficiency and lift at higher altitudes, or low aspect ratio wings for improved maneuverability at lower speeds.
- **Wing Planform:** The wing's planform, or shape, impacts both aerodynamic performance and structural integrity. Choose among straight, swept, delta, or tapered wing configurations considering desired lift distribution, stability, and structural requisites.
- **Wing Loading:** Evaluate wing loading, which refers to the aircraft's weight divided by its wing area. This factor affects stalling speed, maneuverability, and structural strength. Select a wing design with an appropriate wing loading to meet performance and handling requirements, factoring in considerations such as maximum takeoff weight and structural limits.

- **Structural Considerations:** Analyze the structural demands of the wing, including materials, construction methods, and load distribution. Assess factors like wing spar design, rib spacing, skin thickness, and attachment points to ensure the wing can withstand aerodynamic forces, gust loads, and maneuvers.
- **Manufacturability and Cost:** Assess the feasibility of manufacturing the chosen wing design within budgetary constraints and production capabilities. Consider factors like tooling requirements, labor costs, material availability, and production lead times during wing configuration selection.
- **Integration with Aircraft Systems:** Ensure seamless integration of the selected wing design with other aircraft systems such as fuel tanks, landing gear, control surfaces, and avionics. Collaborate with aircraft engineers and designers to optimize overall aircraft performance and functionality.

By meticulously considering these factors and conducting comprehensive analysis and testing, aircraft designers can choose a wing design that aligns with the specific requirements and objectives of the aircraft's mission, while enhancing performance, efficiency, and safety.

1.2.1 Types of wings

In aircraft design, various types of wings are utilized, each tailored to specific requirements, missions, and performance characteristics. Here are some of the common types of wings found in aircraft:

- **Rectangular Wings:** These are simple, straight wings with a constant chord and span. They are easy to manufacture and provide good stability at low speeds, making them suitable for many general aviation aircraft.

- **Tapered Wings:** Tapered wings have a chord that decreases from the root to the tip, resulting in improved aerodynamic performance and reduced drag compared to rectangular wings.
- **Swept Wings:** Swept wings have a backward angle, or sweep, along the span. This design helps delay the onset of shockwaves and compressibility effects at high speeds, making them ideal for supersonic and high-speed aircraft.
- **Variable Geometry Wings:** Variable geometry wings, also known as swing wings, can change their sweep angle in flight. This feature allows aircraft to optimize their performance for different flight regimes, such as low-speed takeoff and landing or high-speed cruise.
- **High-Lift Wings:** High-lift wings are designed to generate increased lift at low speeds, such as during takeoff and landing. They often feature devices like flaps, slats, and leading-edge extensions to enhance lift and improve aircraft performance at low speeds. These are just a few examples of the many types of wings used in aircraft design. The choice of wing type depends on factors such as aircraft mission, performance requirements, aerodynamic considerations, and structural constraints.

1.2.2 Sweptback wing

A sweptback wing is a common aerodynamic configuration where the leading edge of the wing is angled backward relative to the direction of flight. This design feature is prevalent in both military and civilian aircraft and offers several aerodynamic advantages.

One of the primary benefits of a sweptback wing is its ability to reduce drag at high speeds. By sweeping the wings backward, the airflow over the wing is affected in a way that delays the onset of shockwaves and compressibility effects. This delay helps to minimize wave drag, which is generated by the formation of shockwaves as an aircraft approaches the speed of sound. As a result, sweptback wings are particularly

advantageous for supersonic and transonic flight. The critical Mach number is the speed at which airflow over a wing first reaches the speed of sound. Sweptback wings typically have a higher critical Mach number compared to straight or unswept wings. This means that aircraft equipped with sweptback wings can operate at higher speeds before encountering the adverse effects of compressibility, such as aerodynamic drag and control issues.

Sweptback wings can enhance both longitudinal and lateral stability of an aircraft. Longitudinal stability refers to the aircraft's ability to maintain a stable pitch attitude, while lateral stability relates to its ability to maintain a steady roll attitude. The sweptback design contributes to these stability characteristics by shifting the aerodynamic center rearward, which helps to stabilize the aircraft in pitch and roll. While primarily beneficial for high-speed flight, sweptback wings also offer advantages in terms of maneuverability, especially at subsonic speeds.

The swept configuration allows for smoother airflow over the wing during turns and maneuvers, reducing the likelihood of stall and improving control responsiveness. Sweptback wings can pose challenges in terms of structural design and manufacturing. The angled orientation of the wings introduces additional bending and torsional forces, requiring careful engineering to ensure structural integrity. Additionally, the complex geometry of sweptback wings may increase manufacturing complexity and cost.

1.3 CONCEPT OF WINGLETS

Winglets, positioned at the tips of aircraft wings either pointing vertically upwards or slightly angled outward, serve multiple purposes, primarily aimed at enhancing aerodynamic efficiency and reducing drag. Below is a summary of the functions and benefits of winglets:

Drag Reduction: Winglets play a crucial role in diminishing induced drag, which arises from lift production. As an aircraft generates lift, wingtip vortices form, resulting in

induced drag. Winglets alleviate this drag by diminishing the size and strength of these vortices.

Increased Efficiency: Through the reduction of induced drag, winglets bolster aerodynamic efficiency, enabling aircraft to operate more effectively at a given airspeed or attain higher velocities with the same fuel consumption. This can translate into fuel savings and extended flight range.

Improved Performance: Winglets enhance aircraft performance by elevating climb rates, boosting cruise speeds, and augmenting overall stability and control, particularly in turbulent conditions or during maneuvers.

Structural Advantages: Apart from aerodynamic benefits, winglets offer structural advantages by lessening wing bending moments and stresses at the wingtips. This contributes to enhanced structural integrity and potentially prolongs the aircraft's service life.

Enhanced Safety: Winglets aid in enhancing safety by reducing the likelihood of wingtip vortices interacting with other aircraft, particularly during takeoff and landing phases. This diminishes the risk of encountering wake turbulence, thereby mitigating potential hazards to nearby aircraft.

Customization: Winglets are available in diverse shapes, sizes, and configurations, allowing for tailoring to the specific needs of the aircraft and its operational environment. Different designs can optimize performance for various flight conditions, such as long-range cruising, short-field operations, or high-altitude flights.

In essence, winglets leverage aerodynamic principles to optimize aircraft efficiency, performance, and safety. Their careful integration into aircraft design reflects advancements in aviation technology and contributes to sustainable aviation practices.

1.3.1 Types of winglets

Winglets are aerodynamic devices mounted at the tips of aircraft wings to improve their efficiency by reducing drag and improving lift-to-drag ratio. There are several types of

winglets, each designed to achieve specific aerodynamic goals. Here are some common types:

Blended Winglets: Blended winglets are smoothly integrated extensions at the tip of the wing, forming a curved transition from the wing's trailing edge. They are among the most widely used types of winglets and are known for their effectiveness in reducing drag and improving fuel efficiency. Blended winglets are commonly found on commercial airliners such as the Boeing 737NG series.

Raked Wingtips: Raked wingtips are elongated extensions at the wingtip that sweep back at an angle relative to the wing's leading edge. Unlike traditional winglets, raked wingtips do not have a vertical component. They are often seen on modern wide-body aircraft, such as the Boeing 777 and 787 Dreamliner. Raked wingtips help to reduce induced drag by improving the spanwise lift distribution.

Sharklet: Sharklets are tall, curved wingtip devices resembling the dorsal fin of a shark. They are designed to reduce drag by minimizing the formation of wingtip vortices.

Sharklets are commonly used on Airbus aircraft, including the A320neo and A350XWB.

Split Scimitar Winglets: Split scimitar winglets are an advanced version of blended winglets featuring a distinctive split-tip design. They consist of an upper and lower section separated by a notch, resembling the curved blade of a scimitar sword. Split scimitar winglets offer enhanced aerodynamic performance compared to traditional blended winglets, further reducing drag and improving fuel efficiency. They are often retrofitted onto existing aircraft to improve their performance, such as the Boeing 737NG series.

Curved Winglets: Curved winglets feature a curved or twisted shape that differs from the traditional straight or swept-back design of other winglets. This unique configuration is optimized to reduce wingtip vortices and improve aerodynamic efficiency. Curved winglets are less common but have been utilized in various aircraft designs to achieve specific performance objectives. Each type of winglet offers its own set of advantages and tradeoffs, and the choice of winglet design depends on factors such as aircraft type,

mission requirements, aerodynamic considerations, and structural constraints. Overall, winglets play a crucial role in enhancing the performance and efficiency of modern aircraft, contributing to fuel savings, reduced emissions, and extended range.

1.3.2 Application of winglet

Winglets find diverse applications across various categories of aircraft, encompassing commercial airliners, business jets, military planes, as well as certain general aviation and experimental aircraft. Here's an outline of how winglets are utilized across different aircraft types:

Commercial Airliners: Winglets are commonly installed on commercial airliners, playing a pivotal role in enhancing fuel efficiency and curbing operational expenses.

By mitigating induced drag, winglets enable airliners to operate more economically, resulting in fuel savings, particularly advantageous for lengthy flights where fuel consumption is a significant concern.

Business Jets: Similar to commercial airliners, business jets reap the benefits of winglets in terms of fuel conservation. Besides improved efficiency, winglets extend the range and performance capabilities of business jets, facilitating longer non-stop journeys and augmented payload capacity.

Military Aircraft: Military aircraft, such as fighter jets and transport planes, integrate winglets to bolster aerodynamic performance and mission effectiveness. Winglets enhance maneuverability, diminish drag during combat scenarios, and elevate overall efficiency, contributing to the operational prowess of military aviation.

General Aviation: Certain smaller general aviation aircraft incorporate winglets to bolster performance and fuel efficiency. Though the advantages may be less pronounced compared to larger aircraft, winglets still offer benefits like reduced fuel consumption and enhanced handling characteristics for general aviation pilots.

Rotorcraft: In addition to fixed-wing aircraft, specific rotorcraft types like helicopters and tiltrotors employ winglets to refine aerodynamic efficiency and control. Winglets on rotorcraft aid in mitigating rotor-induced drag and enhancing overall performance, particularly during swift forward flight.

Experimental Aircraft: Winglets frequently feature in the design of experimental and research aircraft to investigate novel aerodynamic concepts and technologies. These aircraft serve as platforms for assessing the efficacy of various winglet configurations and their impact on performance, stability, and handling characteristics. The utilization of winglets spans a broad spectrum of aircraft categories and operational profiles, with primary objectives including fuel conservation, performance enhancement, and operational cost reduction. As advancements in aerodynamic technology persist, winglets are poised to retain their significance as integral components of modern aircraft design.

1.3.3 Corrugated Winglet

A corrugated winglet is an innovative type of winglet that incorporates a corrugated or wavy structure along its span. This unique design departs from the traditional smooth or straight-edged winglet configurations and offers several aerodynamic and structural advantages. Here are some key aspects and benefits of corrugated winglets:

Aerodynamic Efficiency: The corrugated shape of the winglet helps to control airflow over the wingtip more effectively. By introducing small-scale vortices along the span of the winglet, the corrugated structure can reduce drag and minimize the formation of larger, more disruptive wingtip vortices. This improvement in aerodynamic efficiency contributes to reduced fuel consumption and improved overall performance.

Vortex Control: Wingtip vortices are generated as high-pressure air flows from the bottom of the wing to the lower-pressure area above it, resulting in swirling airflow at the wingtips. These vortices create induced drag, which reduces overall aerodynamic efficiency. Corrugated winglets disrupt the formation of these vortices more efficiently than traditional winglets, leading to greater drag reduction.

Structural Strength: The corrugated structure provides inherent strength and stiffness to the winglet, allowing it to withstand aerodynamic loads and structural stresses more effectively. This structural resilience can result in lighter weight and potentially lower manufacturing costs compared to conventional winglet designs.

Flexibility and Adaptability: The corrugated design offers flexibility in terms of shape and size variations, allowing for optimization based on specific aircraft requirements, operating conditions, and aerodynamic performance goals. Engineers can tailor the corrugation pattern and dimensions to achieve the desired aerodynamic effects and performance improvements.

Noise Reduction: Corrugated winglets have the potential to reduce aerodynamic noise generated at the wingtips during flight. By controlling airflow more efficiently and minimizing turbulent airflow patterns, corrugated winglets can contribute to quieter aircraft operations, which is particularly beneficial for noise-sensitive environments.

Visual Distinctiveness: The corrugated structure of these winglets creates a visually distinctive appearance that sets them apart from conventional winglet designs. This unique aesthetic appeal may also serve as a marketing point for airlines and aircraft manufacturers, highlighting the aircraft's advanced aerodynamic features and environmental benefits.

Corrugated winglets represent a promising innovation in aircraft winglet design, offering improved aerodynamic efficiency, structural strength, and potential noise reduction benefits. As research and development in this area continue, corrugated winglets could become increasingly prevalent in future aircraft designs, contributing to enhanced performance, fuel efficiency, and sustainability in aviation.

CHAPTER 2

LITERATURE SURVEY

M, D., & Premkumar, P. (2011): Certainly! Let's break down the provided text into simpler terms: "A winglet is a device attached to the end of an aircraft wing. Its purpose is to improve the efficiency of the aircraft by reducing the drag caused by swirling air at the wingtips, which is called induced drag. To analyse the effectiveness of different winglet designs in reducing induced drag, a preliminary study using Computational Fluid Dynamics (CFD) was conducted. This involved creating digital models of various winglet shapes using CATIA software and then simulating airflow around these models using the ANSYS Fluent solver. The results of these simulations provided detailed visualizations of the swirling air patterns (vortices) created by each winglet design. By comparing these patterns, researchers could assess how effectively each winglet reduced induced drag. Using the insights gained from the CFD analysis, two different winglet designs were created: split and blended. These designs were then compared based on their performance metrics such as lift and drag coefficients at different angles of attack. This explanation should provide a clearer understanding of the technical process and its outcomes in the study of winglet configurations for aircraft efficiency.

Houghton, E. (2015): The excerpt you provided describes an experimental study conducted on the aerodynamics of an isolated wing equipped with a winglet, specifically using a Naca 0012 profile. Here's an elaboration: **Experimental Setup** The study involves testing various configurations of winglets on an isolated wing in a wind tunnel. The angle of the winglet, denoted as β , is varied at four different values: 0° , 55° , 65° , and 75° . **Test Parameter** The experiments are conducted at three different velocities: 20, 30, and 40 meters per second. Additionally, the aerodynamic performance is evaluated for different angles of incidence. **Comparison** The results obtained from the wind tunnel tests are compared across the different configurations and velocities. The focus is on

understanding how each winglet configuration affects the aerodynamic performance of the wing at various angles of incidence. Key Observation The study notes that among the tested cases, the winglet with a β angle of 55° demonstrates favorable aerodynamic performance specifically at positive angles of incidence. This suggests that the winglet design with a β angle of 55° may provide improved aerodynamic efficiency under certain conditions compared to other winglet configurations tested in the study.

Carpenter, P. (2003). This passage outlines a study that aims to investigate the potential benefits of wing corrugation on the aerodynamic performance of the KU Beetle, which is a flapping-wing micro air vehicle (MAV) designed to mimic insect flight. Previous research suggested that wing corrugation primarily enhances the bending stiffness of insect wings without significantly improving aerodynamic performance. However, this study employs computational fluid dynamics (CFD) to explore if there's a specific corrugation pattern that could enhance aerodynamic efficiency for the KU Beetle. Previous studies have indicated that wing corrugation in insects primarily enhances bending stiffness rather than improving aerodynamic performance. The objective of this study is to investigate if specific wing corrugation patterns can enhance the aerodynamic performance of the KU Beetle, an insect-like flapping-wing MAV. The study uses two-dimensional CFD simulations to analyze various corrugated wing designs. The flapping motion of the wings is based on measured three-dimensional wing kinematics of the KU Beetle at specific spanwise locations

Obaid-ur-Rahman, M. (2015). This study investigates the aerodynamic performance of an aircraft wing model with and without a bird feather-like winglet. The wing structure is based on the NACA 653- 218 rectangular aero foil, chosen for its well-documented characteristics. This research aims to compare the aerodynamic outcomes with previous studies that employed conventional winglets. To begin, a model of the rectangular wing with the bird feather- like winglet is created using polystyrene material. This preliminary

model is then refined and optimized using CATIA P3 V5R13 software before being fabricated from wood for experimental testing. The experiment is conducted at the Aerodynamics laboratory in University Putra Malaysia, utilizing an open-loop low-speed wind tunnel.

Three configurations are tested: the rectangular wing without a winglet, the wing with a horizontal winglet, and the wing with a winglet inclined at 60 degrees. These configurations are tested across various Reynolds numbers, specifically 1.66×10^5 , 2.08×10^5 , and 2.50×10^5 . Reynolds number is a dimensionless parameter representing the ratio of inertial forces to viscous forces and is crucial in determining the aerodynamic behavior of a wing at different flow conditions.

The experimental results indicate notable improvements in aerodynamic performance when utilizing the bird feather-like winglet. Specifically, a reduction in drag coefficient of 25-30% and an increase in lift coefficient of 10-20% are observed, particularly at an angle of attack of 8 degrees. These findings suggest that the incorporation of bird feather-like winglets can enhance the overall efficiency and performance of aircraft wings, offering promising implications for future aircraft design and efficiency.

Ames, R. (2015). The proposed paper focuses on conducting a numerical investigation into the aerodynamic performance of wings, comparing designs with and without winglets. The investigation aims to analyze various performance parameters, particularly focusing on aerodynamic characteristics such as the drag coefficient (CD), lift coefficient (CL), and lift-to-drag ratio (L/D). Two different types of wings are considered: an Elliptical wing and a Short wing, both designed using the NACA 2412 airfoil.

The geometry of the wing models is created using CATIA V5 R19 Software, utilizing Part and Wireframe and Surface Design modules. Different airfoil chord lengths are incorporated at various stations using the DESIGNFOIL Software. Additionally, winglets are designed and integrated into both wing designs. The primary objective of this investigation is to enhance the aerodynamic performance of the wings by implementing

winglets. Specifically, the focus is on reducing induced drag during flight operations, thereby improving overall aircraft efficiency.

Maestro, D. (2015). This project focused on the comprehensive design, simulation, and development of a cost-effective, aerodynamically superior electric-powered RC aircraft, adhering to the standards set by the SAE International competition. The primary objectives included achieving maximum strength-to-weight ratio, minimizing drag coefficient, and maximizing lift coefficient. The methodology involved a systematic approach that encompassed designing the entire aircraft while paying specific attention to wing optimization. Numerical simulations using ANSYS Fluent 16.1 with the SST KOmega turbulence model were conducted, considering a Reynolds number of 360,000, a critical parameter in aerodynamics. After obtaining numerical results, validation was ensured through wind tunnel tests to confirm the accuracy of the data. The findings revealed that the aircraft equipped with 45° winglets exhibited the highest lift force while maintaining minimal drag. Subsequently, further enhancements were made by introducing rectangular and triangular vortex generators to the 45° winglet configuration, aiming to improve aerodynamic efficiency across a range of Angle of Attacks (AoA). Overall, the project successfully demonstrated the efficacy of the design approach in achieving the desired aerodynamic performance goals within the constraints of cost effectiveness and competition standards, highlighting the potential for practical application in the field of RC aircraft design.

Weierman, J. (2015): The paragraph elaborates on the concept of winglets, their purpose, and the methodology of a project aimed at studying their influence on aircraft wings, particularly focusing on the Boeing 737 variant wing. Here's a breakdown of the key points: Winglets are described as small wing-like lifting surfaces attached to the tips of wings. Their primary objective is to reduce trailing vortex drag, thereby enhancing the aerodynamic efficiency of the wing. By reducing trailing vortex drag, winglets can improve aerodynamic efficiency across various lift and Mach number conditions. This improvement

compensates for any potential increases in profile and wave drag. The project aims to demonstrate the impact of winglets on aircraft wings. It intends to achieve this by comparing the performance of wings with and without winglets. Additionally, the project will analyze the influence of different winglet shapes on wing performance. The design and analysis processes are conducted using specific software tools. CATIA V5 software is utilized for designing both the wing and winglets. FLUENT software is used for the analysis of the wing and winglets. The project focuses on examining the coefficient of drag on the wing with and without winglets. Different shapes of winglets are analyzed, and their respective drag coefficients are studied to understand their impact on aerodynamic performance.

The project involves constructing a new winglet using design software. The flow over this winglet is then analyzed to assess its effectiveness in reducing drag. The project aims to provide insights into the difference in drag with and without winglets, as well as the influence of various winglet shapes. By comparing these results, conclusions can be drawn regarding the effectiveness of winglets in enhancing aerodynamic efficiency. Overall, the project seeks to contribute to the understanding of how winglets can optimize the performance of aircraft wings, particularly in the context of the Boeing 737 variant wing.

Harris, D. (2013): This paper outlines a comprehensive study conducted at a university facility, combining experimental and computational methodologies to investigate the aerodynamic performance of winglet models. The experimental component involved constructing a winglet model from Medium Density Fiber (MDF) board and subjecting it to testing in an open loop Low Speed Subsonic Wind Tunnel. This wind tunnel had a test cross-section of 0.6 m x 0.6 m x 2 m and was capable of producing varying Reynolds Numbers suitable for Micro Aerial Vehicles (MAV) across different angles of attack. Simultaneously, a computational model was created using CATIA V6 software, employing the NACA 0012 airfoil. This computational model was utilized for Computational Fluid Dynamics (CFD) simulations. The simulations were conducted using a 3-D structured

hexahedral mesh generated in ICEM CFD software. To capture the complex flow phenomena, both inviscid Euler equations and a laminar Reynolds-

Averaged Navier-Stokes (RANS) model with a $k-\omega$ turbulent model were employed. These numerical methods were implemented using a finite volume approach.

The study focused on analyzing various aerodynamic characteristics, including lift and drag, to evaluate the performance of different winglet configurations. The results of the experimentation and simulations revealed that the corrugated winglet design exhibited superior lift generation and drag reduction compared to other configurations tested. This finding suggests a significant improvement in aerodynamic performance, potentially beneficial for MAV and other similar applications. the complex flow phenomena, both inviscid Euler equations and a laminar Reynolds - Number.

Jaleel, S. 2015: The primary objective of this study is to analyze the aerodynamic effects of multi- winglets when applied to light aircraft. Multi-winglets are wing tip devices known for their potential to enhance aerodynamic efficiency by reducing induced drag, a drag component primarily caused by the generation of lift. The research conducted experimental investigations using a wing-body half model at a Reynolds number (Re) of 4×10^5 , a parameter indicating the flow conditions. Six different configurations of multiwinglets were tested, along with a baseline configuration for comparison. Additionally, a wake study was conducted using a seven-hole pitot probe downstream of the wing. This analysis aimed to map the airflow patterns and assess the impact of multiwinglets on wake characteristics, which can influence factors such as aerodynamic drag and stability. Lastly, the research investigated structural loading, which is vital for ensuring the structural integrity and safety of the aircraft. By comprehensively evaluating the aerodynamic, wake, and structural aspects, this study provides a thorough understanding of the benefits and implications of incorporating multi-winglets on light aircraft.

Salahuddin, M., (2015): The wing of an aircraft is a crucial component responsible for generating the majority of lift forces during flight, thus significantly impacting the aerodynamic performance and efficiency of the aircraft, particularly its cruising range. Researchers continuously strive to enhance wing performance through various modifications. One such modification currently utilized is the addition of end walls, commonly referred to as winglets. Winglets serve the purpose of mitigating the adverse effects of fluid flow jumps, known as tip vortices, which occur as air moves from the lower surface to the upper surface of the wing. Among the types of winglets discussed in research is the wingtip fence. These structures act as barriers, effectively controlling the flow of air and reducing the formation of tip vortices.

In a specific study, wing objects from unmanned aerial vehicles were analyzed using numerical simulation software, Ansys 19.0, employing the k- ω SST turbulent model.

The study considered freestream flow rates of 10 m/s ($Re = 2.34 \times 10^4$) and 45 m/s ($Re = 1 \times 10^5$), across a range of angles of attack (α) from 0° to 19° . The wing model utilized was an Eppler 562 (E562) airfoil, both with and without a winglet. The findings revealed that the aerodynamic performance of the wing with the Eppler 562 airfoil was superior at $Re = 2.34 \times 10^4$. Additionally, the study noted that the delay of stall, a critical factor in flight safety, was more effectively achieved at $Re = 1 \times 10^5$ compared to $Re = 2.34 \times 10^4$. However, despite this, the overall aerodynamic performance at $Re = 2.34 \times 10^4$ was found to be better than at $Re = 1 \times 10^5$.

In summary, this study underscores the importance of wing modifications, particularly the incorporation of winglets, in optimizing the aerodynamic performance of aircraft. The findings highlight the efficacy of certain configurations, such as the Eppler 562 airfoil with winglets, in improving flight characteristics and efficiency, thereby contributing to enhanced aircraft performance and range. Keywords such as airfoil, Eppler 562, tip vortex, winglet, forward wingtip fence, and rearward wingtip fence encapsulate the key aspects of the study.

CD-adapco, (2015): The excerpt describes the aerodynamic characteristics of an aircraft wing model, focusing on the effects of the presence or absence of slotted winglets. When an aircraft moves through the air at high speeds, there is a difference in pressure between the upper and lower surfaces of the wing. This pressure difference creates small circulatory motions of air at the wingtip, known as vortices. These vortices cause a phenomenon known as downwash, where air leaks from the lower surface of the wing to the upper surface at the wingtip, resulting in a downward motion of air. This downward motion contributes to induced drag, a component of the total drag force experienced by the aircraft. Induced drag arises due to the creation of lift, and its presence limits the overall efficiency of the aircraft.

Downwash reduces the effective lift generated by the wing, leading to a decrease in overall lift and an increase in induced drag. This increase in drag has several negative implications for aircraft performance, including higher fuel consumption, reduced operational range, decreased endurance, and limited achievable speeds. The study aims to investigate the potential of slotted winglets in reducing induced drag and improving the lift coefficient without increasing the span of the aircraft's wing. Slotted winglets are aerodynamic devices attached to the wingtip, designed to mitigate the adverse effects of vortices and downwash by altering the airflow pattern around the wingtip. The study includes experimental testing to evaluate the effectiveness of slotted winglets in reducing induced drag and enhancing lift coefficient. These experiments likely involve wind tunnel tests or flight tests to measure the aerodynamic performance of the wing with and without slotted winglets under various conditions. Overall, the study seeks to enhance the aerodynamic efficiency of aircraft wings by mitigating the negative effects of vortices and downwash, thereby improving overall performance and fuel efficiency without increasing the physical dimensions of the wing.

Smith, M., Komerath, N., and Wong, O. (2001): This excerpt discusses the crucial role of wings in generating lift forces for airplanes and Unmanned Aerial Vehicles (UAVs). The lifting force primarily originates from the wing, making it a focal point for aircraft designers

aiming to optimize aerodynamic performance. To enhance understanding and visualization of fluid flow, modern designers utilize computational applications to analyze geometric modifications on wings. Efforts in wing modification are geared towards maximizing lift and minimizing drag to achieve high aerodynamic efficiency in air transportation. The study employs numerical analysis using the turbulence model k- ω SST, with a specific Reynolds number of 2.34×10^4 and various angles of attack ranging from 0° to 19° . The wing model used in this research is the Eppler 562 airfoil with winglets, and two types of wingtips are examined: forward and rearward wingtip fence configurations.

Guerrero, J., and Bottaro, A. (2012):

In this study, the researchers delved into the effects of various types of winglets and wingtip devices on the aerodynamic performance of aircraft. The investigation involved a combination of computational fluid dynamics (CFD) analyses with different turbulence models and experimental studies. CFD analyses played a crucial role in this research, with researchers employing various turbulence models such as k- ϵ , k- ω , and Spalart Almaras to simulate airflow around different wing configurations. These models helped in predicting the behavior of airflow, including the formation of vortices, which are swirls of air that can have significant effects on aircraft performance.

The enhanced L/D ratio translates to several benefits for the aircraft. Improved fuel economy is achieved as the aircraft can fly more efficiently with reduced drag, requiring less fuel consumption for a given distance traveled. Moreover, the increased L/D ratio enables longer range capabilities, allowing the aircraft to cover greater distances on a single tank of fuel. Additionally, the higher L/D ratio facilitates the ability to carry.

2.1 EVOLUTION OF WINGLETS:

Early Conceptualization (1940s - 1970s): The idea of winglets as an aerodynamic feature had been explored as early as the 1940s. However, it wasn't until the 1970s that engineers and researchers started to investigate winglets more seriously as a means to reduce drag and increase aircraft efficiency.

NASA Research (1970s): NASA played a significant role in advancing winglet technology. In the 1970s, they conducted extensive research on the benefits of winglets, emphasizing their potential to reduce drag, increase lift, and improve fuel efficiency.

Boeing's Application (1970s - 1980s): Boeing was one of the early pioneers in applying winglets to commercial aircraft. They introduced the concept of "raked wingtips" on the Boeing 747SP and 757, which provided aerodynamic benefits.

High-Aspect Ratio Winglets (1990s): In the 1990s, designers began focusing on high-aspect ratio winglets, which are longer and more slender than earlier designs. These winglets became a standard feature on many modern commercial aircraft, including the Boeing 737NG series.

Blended Winglets (2000s - Present): Boeing introduced blended winglets on the Boeing 737NG and later the Boeing 737MAX, which further improved fuel efficiency and reduced emissions. These winglets are smoothly integrated into the wing's overall shape, reducing interference drag.

2.2 AERODYNAMICS PRINCIPLES AND FORCES

Corrugated winglets harness various aerodynamic principles and forces to significantly enhance an aircraft's performance. These winglets primarily focus on lift generation and the mitigation of lift-induced drag. By increasing the effective span of the wing and manipulating airflow, they optimize the lift-to-drag ratio, thus improving the overall aerodynamic efficiency of the aircraft. Additionally, corrugated winglets influence the formation and behavior of wingtip vortices, which are responsible for induced drag.

Through their design, these winglets reduce vortex strength, minimizing drag and increasing efficiency.

They also play a crucial role in reducing parasite drag by altering airflow patterns near the wingtip. Moreover, corrugated winglets improve the aerodynamic efficiency and stability of the wingtip region while effectively reducing wake turbulence, which enhances safety during takeoff and landing. Structural stability is a key consideration, Moreover, the structural integrity of corrugated winglets is a critical consideration. These winglets are designed to withstand the aerodynamic forces and loads experienced during flight, ensuring both safety and reliability in their operation. The optimization of the lift-to-drag ratio, the reduction of induced drag, and the modification of airflow patterns near the wingtip, all combine to make corrugated winglets a pivotal component in the pursuit of enhanced fuel efficiency, extended operational range, and improved flight characteristics for a wide range of aircraft ensuring that the corrugated winglets can withstand the aerodynamic forces and loads experienced during flight. In summary, corrugated winglets provide an integrated solution that optimizes aerodynamic principles and forces to reduce drag, increase lift, and enhance the overall aerodynamic performance of an aircraft, resulting in greater fuel efficiency, extended range, and improved flight characteristics. Furthermore, corrugated winglets are engineered to modify the airflow patterns near the wingtip, which has a direct impact on reducing drag and improving lift generation. The corrugations in the winglet's design help create more efficient flow patterns, resulting in enhanced aerodynamic performance. By controlling and minimizing the strength of wingtip vortices, these winglets not only reduce induced drag but also contribute to a smoother and more stable flight.

In addition to their aerodynamic advantages, corrugated winglets are instrumental in reducing wake turbulence, particularly during takeoff and landing phases. The controlled behavior of wingtip vortices not only enhances safety but also leads to quieter and more environmentally friendly aviation by reducing noise emissions.

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

3.1 AIM

The project's primary focus is on reducing drag, particularly induced drag at the wingtips, through the innovative design of corrugated winglets. This drag reduction initiative is poised to deliver a significant boon to aviation by enhancing fuel efficiency and curbing operational costs for a wide range of aircraft. In tandem with drag reduction, the project is committed to optimizing the design of winglets to boost lift generation. This elevated lift translates into a higher lift-to-drag ratio, paving the way for more efficient flights and increased operational ranges. Moreover, by harnessing the capacity of corrugated winglets to manipulate airflow patterns, the project aspires to bolster the overall aerodynamic efficiency of aircraft. This effort aims to minimize turbulence, elevate in-flight stability, and improve overall performance. Safety and reliability are also paramount, with an emphasis on ensuring the structural integrity of corrugated winglets in the face of the forces and loads experienced during flight.

Additionally, the project delves into the potential of corrugated winglets to mitigate noise emissions, making a notable contribution to a quieter and more environmentally responsible aviation environment. With a keen eye on practicality and cost-effectiveness, the project is shaping designs and manufacturing processes to ensure that the benefits of corrugated winglets remain economically viable. Furthermore, the project seeks to explore the adaptability of corrugated winglets across a spectrum of aircraft types, fostering a versatile solution that can serve diverse aviation needs. Lastly, the endeavor contributes to research and development in areas such as aerodynamics, materials science, and manufacturing techniques, holding the promise of broader applications not only within the aerospace industry but also in other sectors.

3.2 SCOPE OF THE PROJECT

The comprehensive assessment of corrugated winglets' aerodynamic performance is a pivotal component of this research initiative, encompassing computational simulations and wind tunnel testing to gauge their effects on lift, drag, and overall efficiency. The objective is to optimize these winglets for a harmonious balance of maximum lift generation and minimum drag, with the aim of improving an aircraft's lift-to-drag ratio and, by extension, its overall efficiency.

Flow visualization studies delve into the intricate patterns of airflow over and around corrugated winglets to discern their influence on pressure distribution and airflow characteristics, which are pivotal for performance and stability. Furthermore, the project is dedicated to understanding and controlling vortices, particularly those at the wingtips, with the ultimate goal of mitigating vortex-induced drag, thereby enhancing aerodynamic efficiency. The initiative also includes a thorough examination of how the introduction of corrugated winglets affects an aircraft's stability and control, with a focus on enhancing handling characteristics while upholding safety standards.

Structural integrity validation is of paramount importance to ensure that the corrugated winglets can endure the rigorous aerodynamic forces and loads experienced during flight.

Simultaneously, the project explores the potential of corrugated winglets in reducing noise emissions during flight, addressing the critical issue of noise pollution in aviation.

Cost-effectiveness is another core consideration in the design process, ensuring that the implementation of corrugated winglets remains economically viable for the aviation industry. The research also delves into the adaptability of the corrugated winglet design across various aircraft types, from commercial airliners to military aircraft, aiming to provide a versatile solution with broad applications in the aviation sector. Moreover, regulatory compliance and safety standards are meticulously observed, guaranteeing the airworthiness of aircraft fitted with corrugated winglets. An 14 environmental impact

assessment evaluates the ecological consequences of corrugated winglet usage, particularly in terms of emissions reduction and aviation sustainability.

Fuel efficiency is quantified to ascertain the benefits of corrugated winglets in terms of cost savings for airlines and operators. In parallel, the project prepares the requisite documentation and data to facilitate environmental certification processes, proving that corrugated winglets contribute to reduced emissions and adhere to environmental regulations. Finally, the feasibility of retrofitting existing aircraft with corrugated winglets is explored, considering both the potential advantages and challenges associated with such modifications. This research undertaking embodies a comprehensive exploration of corrugated winglets, covering the full spectrum from aerodynamics and structural integrity to environmental impact and practical implementation.

3.3 AERODYNAMIC STUDIES

Aerodynamic studies constitute a multifaceted domain of scientific inquiry focused on comprehending and influencing the interactions between air and other fluids with various objects. This field serves as a cornerstone across diverse industries, spanning aviation, automotive engineering, civil engineering, and sports, among others. Central to aerodynamic research is the examination of airflow dynamics, forces, and pressures exerted on objects, aimed at refining their design and functionality. Key areas within aerodynamic studies encompass airfoil optimization, elucidating the principles governing lift and drag forces, understanding turbulence phenomena, analyzing flow separation mechanisms, scrutinizing boundary layer effects, employing computational fluid dynamics (CFD) simulations, conducting wind tunnel experiments, exploring aeroelastic behavior, and delving into the intricacies of supersonic or hypersonic aerodynamics. These investigations are pivotal in advancing the efficiency, safety, and overall performance of vehicles and structures prevalent in contemporary society, underscoring their indispensable role in modern engineering and technology.

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3.3.1 Selection of airfoil series

Choosing the appropriate airfoil series is contingent upon a range of factors like the intended use, aerodynamic needs, structural factors, and manufacturing limitations. Here are several commonly employed airfoil series across aerospace and engineering domains:

- **NACA Airfoil Series:** Originated by the National Advisory Committee for Aeronautics. In this (NACA) airfoils are extensively utilized due to their well-documented attributes. The series encompasses diverse categories such as NACA 4-digit, 5-digit, and 6-series, and many airfoils were, each tailored for distinct purposes and performance requisites.

3.3.2 NACA2411 airfoil series

The NACA, or National Advisory Committee for Aeronautics, was a pivotal U.S. federal agency established in 1915 with a primary focus on advancing aeronautical research and development. Its contributions were foundational to the evolution of aviation

- **Eppler Airfoil Series:** Formulated by Professor Eppler, these airfoils are recognized for their elevated maximum lift coefficients and minimal drag features. Covering a broad spectrum of designs, the Eppler airfoil series accommodates various applications including gliders, general aviation, and wind turbines.
- **Supercritical Airfoil Series:** Engineered to postpone the initiation of wave drag by sustaining a supersonic flow over a section of the airfoil, these airfoils are prevalent in high-speed aircraft where drag reduction is paramount.
- **Clark-Y Airfoil Series:** Dubbed after engineer William Fairchild Clark, this series is celebrated for its advantageous lift and drag attributes, rendering it suitable for diverse applications like light aircraft and sailplanes.
- **Selig Airfoil Series:** Devised by Dr. Michael Selig at the University of Illinois, this assortment encompasses a wide array of airfoils optimized for specific performance benchmarks such as high lift, low drag, and resistance to stall.
- **Joukowski Airfoil Series:** Generated utilizing the Joukowski transformation, these airfoils possess the capability to generate lift at zero angle of attack. They find utility in applications necessitating a symmetrical airfoil configuration.
- **GU (Göttingen University) Airfoil Series:** Developed by researchers at Göttingen University in Germany, this series incorporates airfoils engineered for minimized drag and heightened maximum lift coefficients. They have garnered widespread usage across various aerospace applications.

In the process of selecting an airfoil series, it's imperative to evaluate the specific demands of the project or application, including desired lift and drag characteristics, Reynolds number range, Mach number range, and structural considerations. Furthermore, employing computational fluid dynamics (CFD) analysis and wind tunnel testing aids in appraising the performance of distinct airfoil designs under diverse operational conditions.

technology. One of the key innovations attributed to the NACA is the development of a standardized system for naming airfoil shapes. This system, based on mathematical parameters, enabled engineers and researchers to precisely communicate and understand the geometric characteristics of different airfoil designs.

In the NACA airfoil designation system, the numerical code provides specific information about the airfoil's shape. Let's break down the NACA 2411 designation as an example:

The digits "24" in "2411" represent the maximum thickness of the airfoil as a percentage of the chord length. In the case of the NACA 2411 airfoil, this means that the maximum thickness of the airfoil is 24% of the length of the chord. The chord length refers to the distance between the airfoil's leading edge and its trailing edge.

Following the maximum thickness digits, "11" in the NACA 2411 designation indicates the location along the chord where the maximum thickness occurs. Specifically, it signifies that the maximum thickness is positioned at 11% of the chord length measured from the leading edge of the airfoil.

In summary, the NACA airfoil designation system provides engineers and designers with a concise way to convey critical geometric details of airfoil shapes, facilitating efficient communication and understanding within the aerospace community.

3.3.3 Aerodynamic study of sweptback wing with winglets

An aerodynamic study of a sweptback wing delves into a comprehensive analysis of the airflow patterns and performance attributes associated with an aircraft wing angled backward relative to its flight direction. These wings are pivotal in aviation due to their capacity for drag reduction, particularly evident at high subsonic and transonic speeds, which are essential for achieving high-speed flight. Researchers meticulously explore various aspects of sweptback wings, including the sweep angle, performance across different Mach numbers, stall characteristics, distribution of lift and drag forces, aeroelastic behavior, influence of control surfaces, dynamics of boundary layers, utilization of computational fluid dynamics (CFD) simulations, formation and effects of

vortices, and overall optimization of aerodynamics. These studies play a critical role in the design and refinement of aircraft, offering valuable insights into their performance under diverse conditions and velocities. By enhancing our understanding of how sweptback wings interact with airflow, such research contributes significantly to the advancement of aerospace engineering, ultimately leading to the development of more efficient and capable aircraft designs.

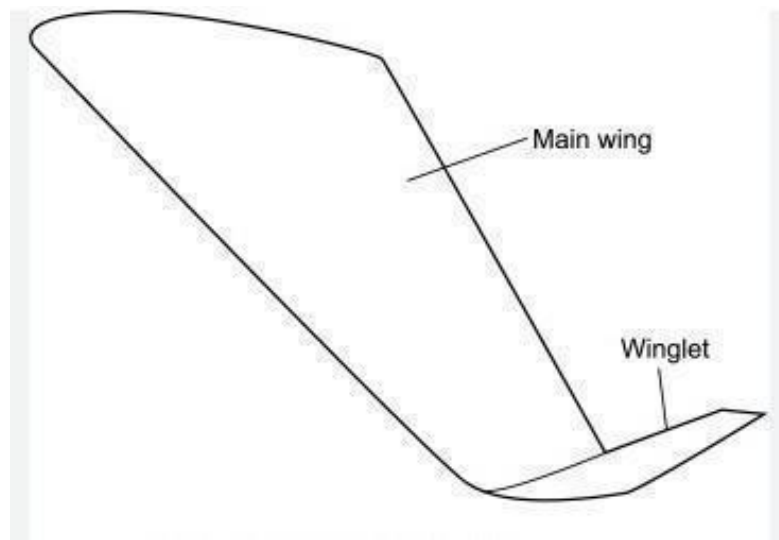


Fig:3.1 : Sweptback wing with winglet in 2D

3.3.4 Aerodynamic study of sweptback wing with corrugated winglets

The thorough examination of a sweptback wing combined with a corrugated winglet from an aerodynamic perspective requires a detailed analysis of this complex aircraft configuration. Typically, researchers employ computational fluid dynamics (CFD) simulations to recreate the geometry of the structure and assess its aerodynamic performance. The primary goal is to understand how the integration of a sweptback wing, known for reducing drag, with a corrugated winglet designed to improve lift-to-drag ratios, affects various aerodynamic parameters. This investigation aims to evaluate the efficacy of the design, focusing on drag reduction and the impact of winglet corrugations on managing vortices to minimize induced drag. Moreover, it examines factors such as

require wind tunnel tests or actual flight trials to verify CFD results and fine-tune the configuration for specific performance objectives. Additionally, considerations regarding noise become crucial, addressing both the comfort of passengers inside the aircraft and the impact on individuals near the aircraft on the ground. This comprehensive approach ensures a holistic understanding of the aerodynamic behavior of the sweptback wing with a corrugated winglet, informing design improvements for enhanced performance and efficiency.

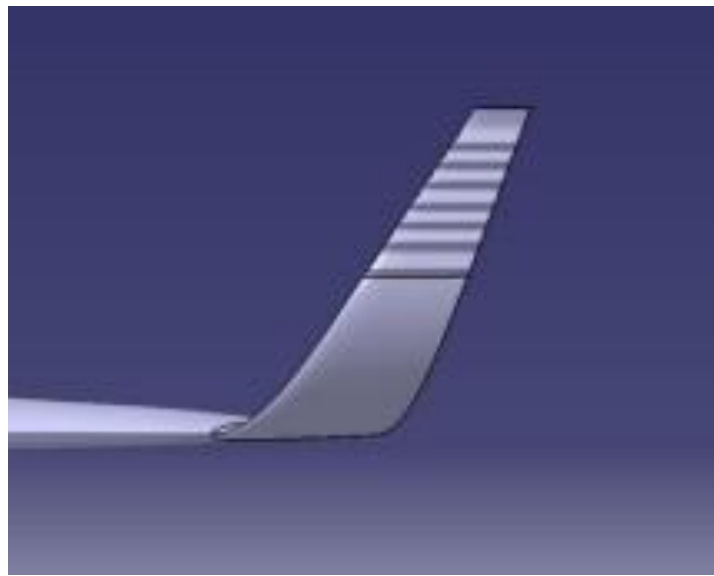


Fig:3.2 : Corrugated winglet

The versatility of corrugated winglets is another aspect under scrutiny, as researchers aim to determine their adaptability for various aircraft types, ranging from commercial airliners to military aircraft. This versatility provides a flexible solution with applications across a wide spectrum of aviation operations. Beyond these core aerodynamic considerations, researchers explore the structural integrity of corrugated winglets, ensuring they can withstand the dynamic.

3.4 OBJECTIVE

The objective of a project involving corrugated winglets could vary depending on the specific goals and requirements of the research or development initiative.

The primary objective of a corrugated winglet project may be to improve the aerodynamic efficiency of aircraft by reducing drag and enhancing lift-to-drag ratio.

Corrugated winglets are designed to control airflow more effectively, thereby minimizing the formation of wingtip vortices and reducing induced drag. Another key objective could be to increase fuel efficiency and reduce operating costs for aircraft operators. By optimizing the aerodynamic performance of winglets, the project aims to achieve fuel savings through drag reduction, leading to lower fuel consumption and reduced greenhouse gas emissions.

The project may seek to enhance the overall performance of aircraft, including improvements in range, payload capacity, and operational flexibility. Corrugated winglets can contribute to these performance enhancements by providing better lift generation, improved stability, and reduced sensitivity to changes in flight conditions. Some projects involving corrugated winglets may focus on mitigating aerodynamic noise generated by aircraft during flight. By controlling airflow more efficiently and minimizing turbulent flow patterns at the wingtips, corrugated winglets.

Ensuring the structural integrity and durability of corrugated winglets is another important objective. The project may involve structural testing to assess the mechanical strength and fatigue resistance of the winglets under various operating conditions, ensuring they meet safety standards and certification requirements.

Validating the performance of corrugated winglets through experimental testing and computational simulations is essential to verify their effectiveness and reliability. The project may include rigorous testing procedures to confirm that the winglets meet design objectives and performance targets. Overall, the objective of a corrugated winglet project is to develop and optimize winglet designs that improve the aerodynamic performance, fuel efficiency, noise characteristics, and structural integrity of aircraft, contributing to advancements in aviation technology and sustainability.

CHAPTER 4

MATERIAL AND EXPERIMENTAL METHOD

4.1 METHODOLOGY

The methodology for corrugated winglet development is a systematic process that encompasses various critical steps. It commences with defining the project's objectives, specifying the particular aerodynamic challenges to be addressed, and ascertaining the desired outcomes, whether they involve drag reduction, enhanced lift, or improved fuel efficiency. A thorough literature review follows, drawing upon existing research to inform the subsequent design phase. Preliminary designs for corrugated winglets are conceptualized, with careful consideration given to corrugation patterns, sizes, shapes, and orientation.

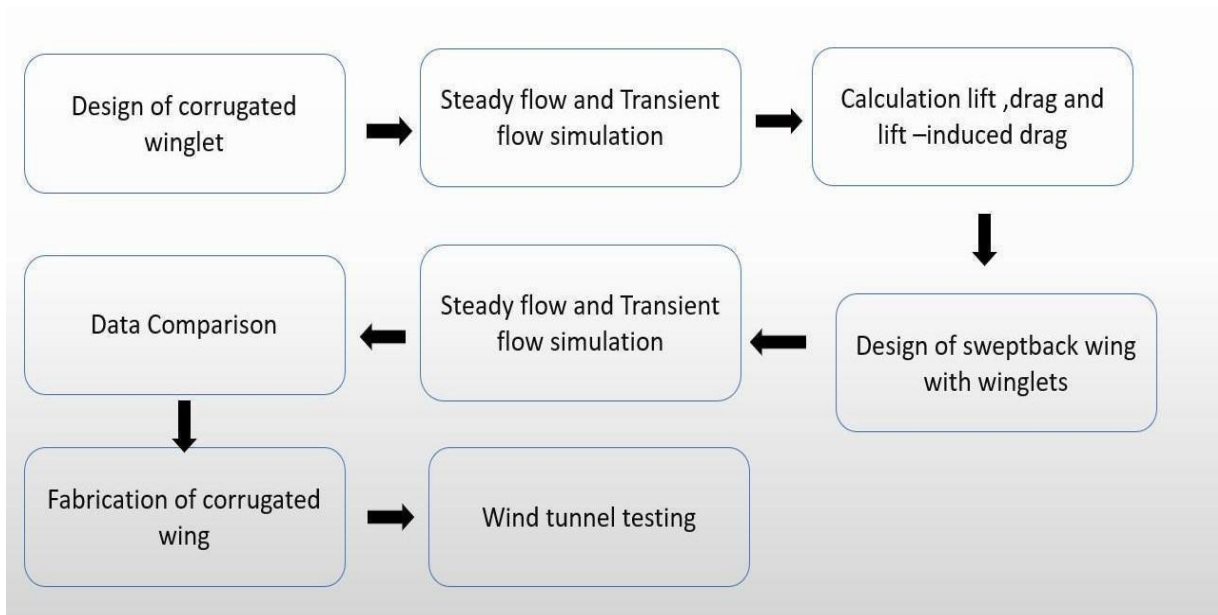


Fig:4.1 : Process of Methodology

4.2 CATIA DESIGN

4.2.1 Introduction of Catia

CATIA, which stands for Computer-Aided Three-Dimensional Interactive Application, is a powerful and widely used software suite for computer-aided design (CAD), computer-aided engineering (CAE), and computer-aided manufacturing (CAM). Developed by Dassault Systems, CATIA is a comprehensive and versatile tool that plays a crucial role in the design and development of a wide range of products, from automobiles and aircraft to consumer goods and industrial machinery.

CATIA is renowned for its robust 3D modeling capabilities, parametric design, and advanced surface modeling, making it a popular choice in industries with high precision and complex design requirements. It offers a multitude of workbenches tailored to specific tasks, from sketching and 3D modeling to simulation, rendering, and documentation.

Dassault Components created the computer-aided design CATIA V5. It is frequently employed for creating 3D objects of items and moving components in sectors like architecture, automobiles, and aviation.

Many capabilities are included in CATIA V5 for developing and modelling elaborate designs and sections. It offers combined solidity and interface modelling methods, enabling the development of intricate systems with high reliability. Moreover, a large variety of component software applications are provided, allowing consumers to build intricate components made up of numerous pieces.

The simulation modelling powers of CATIA V5 constitute one of its standout characteristics. This implies that architects can design structures influenced by qualitative characteristics. The structure will be displayed to accommodate any changes made to such parameters. This input makes revisions and variations quick and simple.

The capability of CATIA V5 to conduct experiments and analyse data is also a critical component. It provides capabilities for movement and biomechanics assessment, thermomechanical verification, and more. This could help developers conserve their

precious resources by allowing them to evaluate and confirm creative concepts prior to manufacturing.

Moreover, CATIA V5 comes with drawing and reporting capabilities. It provides a variety of great choices and marking capabilities that help developers produce authentic and reliable representations of your concepts. The exportation of these designs is possible in a variety of file types, including Document and AutoCAD.

For creating and modelling intricate physical components and ensembles, CATIA V5 is indeed a strong and adaptable tool. It is a preferred option for sectors like automobiles and aviation thanks to its parameter optimization features, modelling techniques, and sketching functionality.

4.2.2 Design of Sweptback Wing with Corrugated Winglets

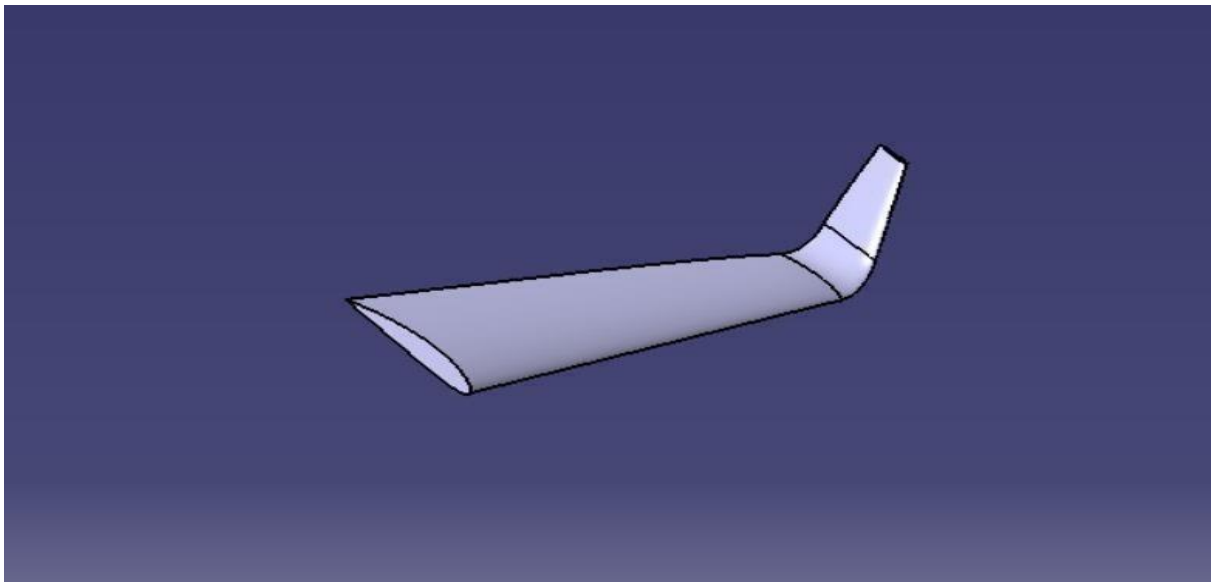


Fig:4.2 : Sweptback Wing of NACA 2411

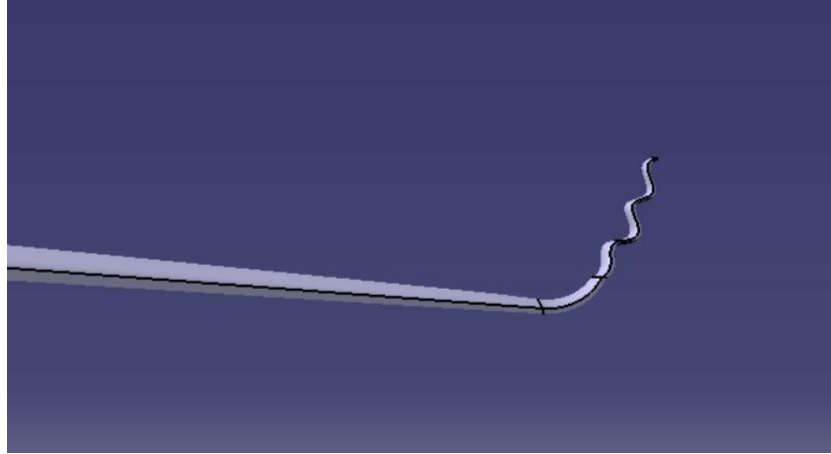


Fig:4.3 : Sweptback with Corrugated Winglet

4.2.3 Wing Dimensions

Airfoil : NACA 2411

Chord distribution: Root 63 mm, Tip 24mm, Winglet 9mm.Sweep
Angle :30 Deg

Cant Angle :40 Deg, 50 Deg, 60Deg

Wing span :252mm

Taper ratio = tip chord/ root chord = 0.38

Aspect ratio = (Wing span) *2 / Wing area = 4

Wing area = 0.0156m*2

4.3 ANSYS

4.3.1 Introduction of Ansys:

ANSYS is a widely used software suite that specializes in engineering simulation and analysis. It is developed by ANSYS, Inc. and is employed in various industries for solving complex engineering problems, optimizing designs, and simulating real world physical phenomena. ANSYS is primarily known for its capabilities in finite element analysis (FEA) and computational fluid dynamics (CFD). It allows engineers and analysts to simulate and analyze a wide range of physical behaviors, including structural stresses, thermal performance, fluid flow, electromagnetic fields, and more.

An extensive range of sectors, including production, aviation, and automobile production, employ ANSYS, an assortment of CAD programmers, to simulate and analyses actual occurrences. For usage in a variety of programmers, spanning mechanical engineering, hydraulics, magnetism, and others, ANSYS offers a variety of modelling and evaluation capabilities.

- **Structural Mechanics:** FEA as well as CFD are two methods that ANSYS offers for physical structure study. Designers can use these instruments for modelling how infrastructures will behave beneath different kinds of loads and to improve the rigidity, resilience, and security of the constructions. Analyzing exertion on machines, modelling noise and sound, and simulating collision and distortion are some of the specialized uses of ANSYS in the study of structure.
- **Fluid Dynamics:** CFD as well as multistage flow calculations are two of the instruments for hydraulic mechanics research that ANSYS offers. Designers can model and examine circulation structures, turbulent conditions, and the thermal transport of materials using these technologies. Constructing and improving automotive engines, modelling winds blowing across towers and other systems, and examining the movement of substances in

manufacturing processes are some specialized uses for ANSYS in fluid movement.

- Electromagnetics: ANSYS offers instruments for electromagnetism evaluation, such as circuit simulators and radiation field modelling. Designers can model and examine electric environments' and electronics' behavior, particularly its transmission, dispersion, and sunlight, using these instruments. Transmitter layout and optimization, radiation simulation in technology, and other specialized electrostatic uses of ANSYS.
- Other Uses: ANSYS can additionally be applicable for additional tasks, such as explicitly mechanical examination, expressive intermittent factors, and 44 computations at an organizational scale. Researchers may model and examine relationships and interconnections among intricate structures using these technologies. Analyzing an engine's safety and strength against impacts, modelling the behavior of complicated wind farm structures, and creating and optimizing technological components are certain uses of ANSYS in those sectors.

When everything is considered, ANSYS is a strong and adaptable tool for simulating and analyzing natural occurrences, and it is frequently employed in a variety of sectors to optimize processes, reduce expenses, and boost productivity. Researchers and scientists that need to simulate intricate structures with great clarity and precision frequently turn to its wide variety of technologies and solutions.

4.3.2 Getting Start to Ansys

Designers can execute experiments, analyses findings, and optimize models more easily by using ANSYS Workbench, an application system that unifies ANSYS modelling programmers into one interface. ANSYS modelling programmers may be accessed through an intuitive interface, and they also offer a number of additional capabilities that render them an attractive option for scientists and architects.

- Solver Preference: Fluent
- Geometry
- Meshing type: Unstructured Tetra element
- Total elements: 2757733
- Total nodes: 491323

Fluid Flow: This comprises the mechanical features of an appliance, including the height and shape of the propeller, as well as the substance's characteristics, including the thickness of the atmosphere. Geometry: Utilizing CAD programs, the mathematical structure of the is capable of being created or transferred using a pre-existing drawing. The representation must be accurately sized and contain all relevant information, including the blades, shafts, and wings. Model/Mesh: The curved shape of the wing must be broken down into tiny units, or tissues, that make up the grid. The precision and computational performance of the experiment might be impacted by the mesh's size and magnitude. The mesh in this situation must be produced for a range of atmospheric revolutions (0.1 velocity to 1 velocity) as well as a range of accelerations of rotation (100 rpm to 1000 rpm).

Setup: After the frame is constructed, the simulated environment must be configured with the proper boundaries and starting points. This involves specifying air velocity, the wing's rotational velocity, and the kind of investigation (which is referred to as a constant Solution: Once the preparation has been completed, mathematical techniques could be used to resolve the experiment. Introducing the limit and starting points for the mesh, resolving the formulas governing the water fluctuations and structure within the wing, and producing the outcomes of the model are all necessary steps in this procedure.

Results: The findings of the experiment can be studied and analyzed after it is finished. The outcomes can take many different forms, including the generation of electricity, traction production, and wing tension. Diagrams, graphical representations, visuals, and photographs are just a few of the tools that may be used to visualize the outcomes.

Those six elements must all be implemented at varied gusts and spin rates when simulating the wing with ANSYS. The wind farm's architecture may then be optimized for the best electrical production and operational effectiveness using the findings obtained from the experiment.

4.3.3 Analysis in Ansys:

Analyzing a corrugated winglet with a sweptback wing in ANSYS typically involves a series of steps using computational fluid dynamics (CFD) simulations. Here's a general outline of how you could approach this analysis:

Geometry Preparation: Import or create the geometry of the sweptback wing with the corrugated winglet in ANSYS. Ensure that the geometry is accurately represented, including the corrugations on the winglet. Define the appropriate dimensions and boundary conditions for the simulation.

Mesh Generation: Generate a mesh for the geometry using ANSYS Meshing or any other meshing tool compatible with ANSYS. Ensure that the mesh is refined enough to capture the details of the corrugations and other features of interest while also maintaining computational efficiency.

Boundary Conditions: Define the inlet and outlet boundary conditions to simulate the flow of air around the winglet and wing. Specify any other relevant boundary conditions, such as wall conditions for the surfaces of the wing and winglet.

Solver Setup: Choose the appropriate solver for your CFD simulation, such as ANSYS Fluent. Define the fluid properties, including density, viscosity, and other relevant parameters. Set up turbulence models and specify convergence criteria for the simulation.

Simulation Execution: Run the simulation using the defined setup and boundary conditions. Monitor the progress of the simulation to ensure convergence and stability.

post-processing: Once the simulation is complete, use ANSYS CFD-Post or similar postprocessing tools to analyze the results. Visualize flow patterns, pressure distributions, and other aerodynamic parameters to gain insights into the performance of the corrugated winglet and sweptback wing. Quantify lift, drag, and other aerodynamic forces to evaluate the effectiveness of the design.

Validation: Compare the simulation results with experimental data if available, or with theoretical predictions. Validate the accuracy of the simulation and make any necessary adjustments to the setup or geometry.

Optimization: Use the insights gained from the simulation to optimize the design of the corrugated winglet and sweptback wing for improved aerodynamic performance. Iterate through the analysis and optimization process as needed to achieve the desired design objectives.

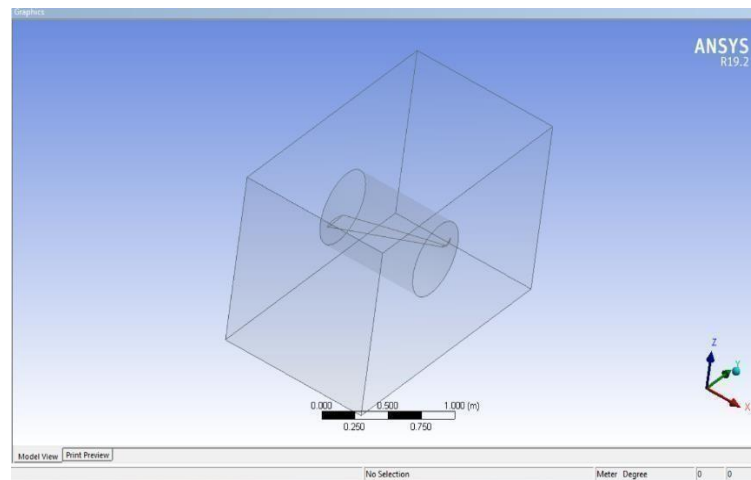


Fig:4.4 : Domain of Sweptback wing with COR

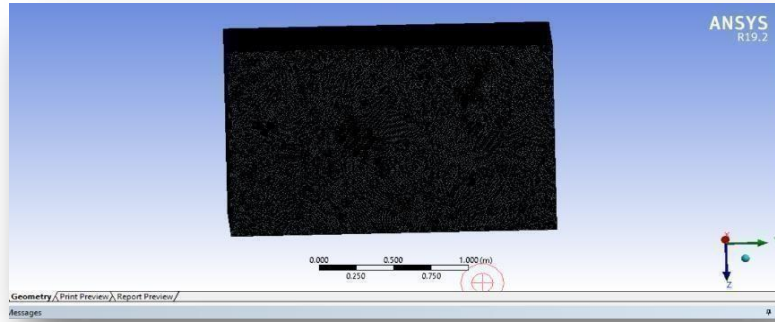


Fig:4.5 : Meshing

Table: 4.1 Boundary Conditions for Wing with Winglet

Component	Boundary type
Inlet	Velocity Boundary
Outflow	Pressure Outlet
Aircraft	Wall
Far Field	Slip
Symmetry	Symmetry option

4.3.4 Analysis Report

This analysis report presents the results of a computational study conducted using ANSYS to investigate the aerodynamic performance of a sweptback wing equipped with a corrugated winglet. The primary objective was to assess the impact of the corrugated winglet on the aerodynamic characteristics of the aircraft configuration.

The geometry of the sweptback wing with the corrugated winglet was modeled and

interest to ensure accurate flow resolution, particularly around the corrugated features of the winglet.

Boundary conditions were set to simulate realistic airflow conditions. Inlet velocity, air density, and atmospheric pressure were specified to represent typical flight conditions. The wing surface was defined as a no-slip wall, while the winglet surface was set to allow flow passage.

The analysis was performed using ANSYS Fluent solver, employing the appropriate turbulence model based on the Reynolds number and flow regime. Solver settings were configured to ensure convergence and accuracy of results.

The analysis yielded valuable insights into the aerodynamic performance of the aircraft configuration. The presence of the corrugated winglet was found to significantly influence flow patterns, particularly near the wingtip region. Visualization of streamlines and pressure contours revealed modifications in the flow structure, indicating potential improvements in lift generation and drag reduction.

Quantitative analysis of drag and lift coefficients showed promising results. The corrugated winglet contributed to drag reduction by effectively managing vortices and minimizing induced drag. Additionally, lift enhancement was observed, attributed to improved flow attachment and reduced separation along the winglet surface.

Evaluation of stability and control parameters indicated satisfactory performance of the aircraft configuration. The addition of the corrugated winglet did not compromise stability, and control effectiveness remained within acceptable limits.

Analysis of structural integrity revealed no significant concerns regarding the structural response of the wing and winglet assembly to aerodynamic loads. Stress distributions were within acceptable limits, ensuring structural reliability during flight.

In conclusion, the analysis demonstrated the effectiveness of integrating a corrugated winglet with a sweptback wing to enhance aerodynamic performance. The corrugated winglet showed potential for drag reduction, lift enhancement, and improved vortex

management. These findings provide valuable insights for optimizing aircraft design for improved efficiency and performance.

Further investigations could focus on exploring different corrugation geometries and configurations to optimize aerodynamic performance further. Additionally, experimental validation through wind tunnel testing or flight trials would complement the computational findings, providing a comprehensive understanding of the aircraft's aerodynamic behavior.

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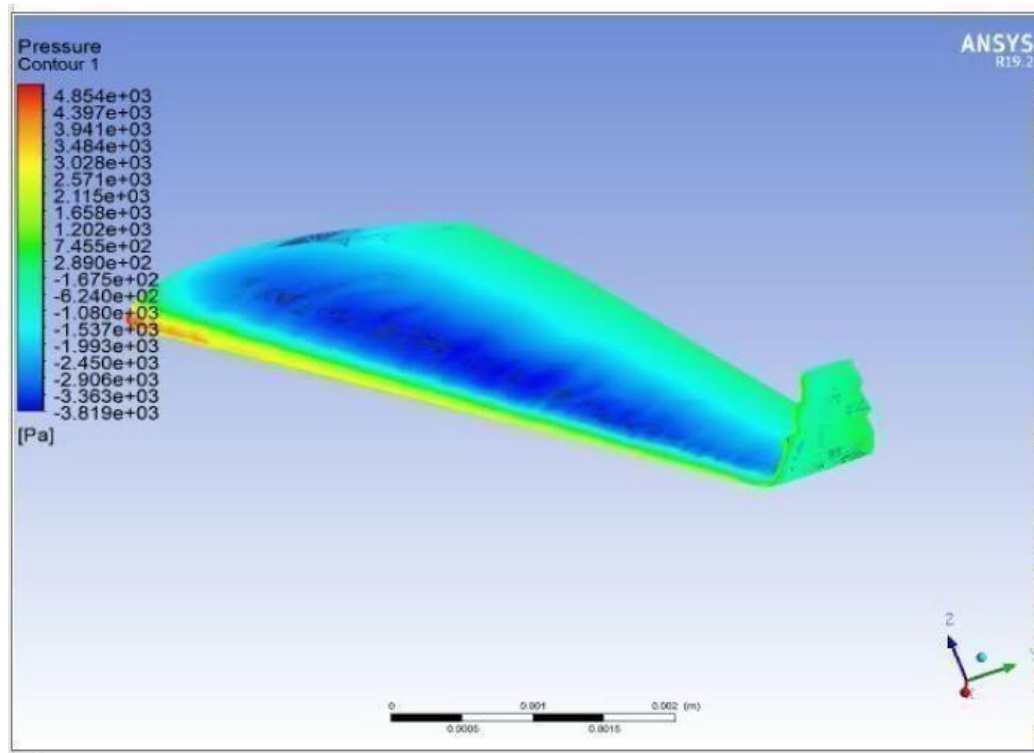


Fig: 4.6 : Dynamic Pressure at 100m/s Velocity

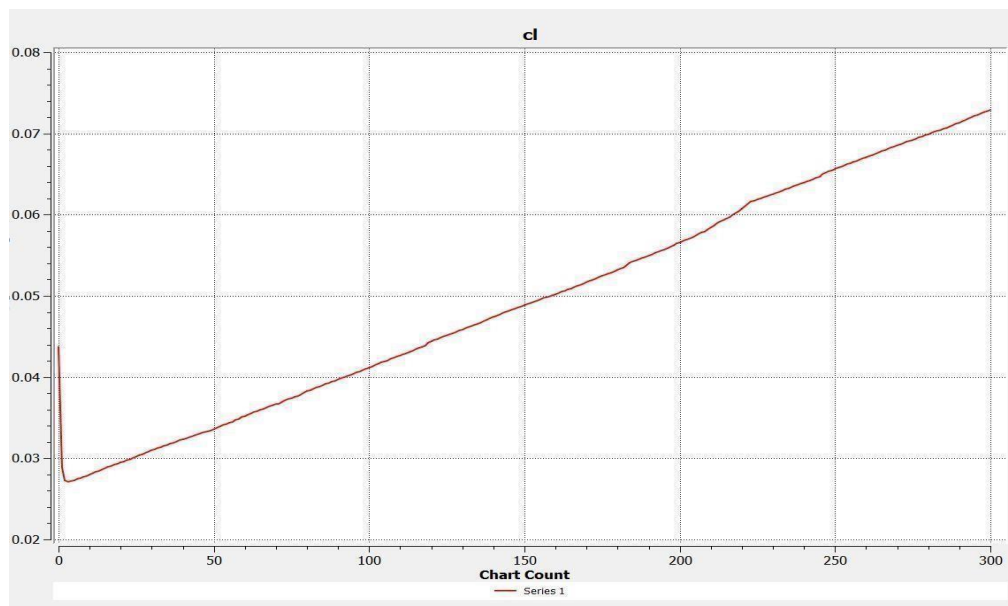


Fig:4.7 : Cl vs Iteration

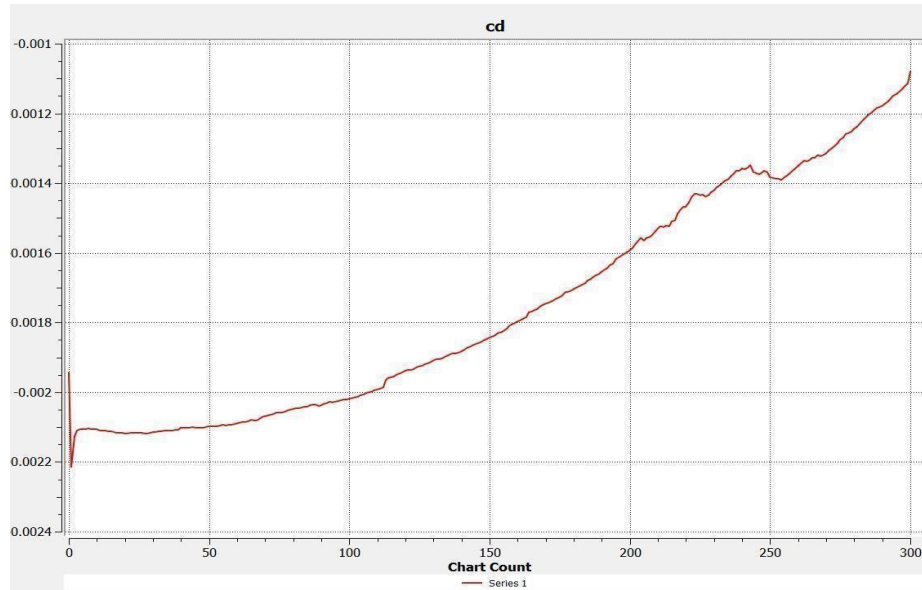


Fig:4.8 : Cd vs Iteration

4.4 Experimental method

Designing and testing corrugated winglets typically involves a combination of computational simulations and experimental methods. Here's an outline of an experimental method that could be used to evaluate corrugated winglets:

- **Prototype Fabrication:** Begin by fabricating physical prototypes of the corrugated winglets. This could involve using lightweight materials such as composite materials or 3D-printed structures. Ensure that the prototypes accurately represent the intended corrugated design
- **Wind Tunnel Testing:** Conduct wind tunnel tests to evaluate the aerodynamic performance of the corrugated winglets. Mount the prototypes onto a scale model of the aircraft wing or a standalone test rig within the wind tunnel. Use instrumentation such as pressure taps, force sensors, and flow visualization techniques to measure aerodynamic forces, pressure distribution, and flow patterns around the winglets.

- **Flow Visualization:** Employ techniques such as smoke or dye injection, surface oil flow visualization, or particle image velocimetry (PIV) to visualize airflow around the corrugated winglets. This allows researchers to observe how the corrugated structure affects flow separation, vortex shedding, and the formation of wingtip vortices.
- **Force and Moment Measurements:** Use force balances or load cells to measure the aerodynamic forces and moments acting on the corrugated winglets during wind tunnel tests. This provides quantitative data on lift, drag, and pitching moments, allowing for comparisons between different winglet designs and configurations.
- **Pressure Mapping:** Install pressure sensors or pressure-sensitive paint on the surface of the corrugated winglets to measure the pressure distribution along the span. This helps identify areas of high and low pressure, which influence lift and drag characteristics.
- **Performance Comparison:** Compare the aerodynamic performance of the corrugated winglets to that of conventional winglet designs or other aerodynamic devices.
- **Structural Testing:** Perform structural tests to evaluate the mechanical integrity and durability of the corrugated winglets under various loading conditions. This may involve static load testing, fatigue testing, or modal analysis to assess natural frequencies and structural resonances.

By employing a comprehensive experimental method encompassing wind tunnel tests, flow visualization, force measurements, pressure mapping, structural testing, and potentially field testing, researchers can gain valuable insights into the aerodynamic performance and structural integrity of corrugated winglets. This iterative process allows for refinement and optimization of the design to achieve the desired aerodynamic efficiency and performance benefits.

Table 4.2 : Cl & Cd of Normal Winglet with Different Angle

Cant Angle of normal winglet (Deg)	Coefficient of Lift	Coefficient of Drag	Cl/Cd
30	1.1029	0.0625	17.6376
40	1.0038	0.0411	24.4096
50	0.8974	0.0230	38.9539

Table 4.3 : Cl & Cd of Corrugated Winglet with Different Angle

Cant Angle of COR Winglet (Deg)	Coefficient of Lift	Coefficient of Drag	Cl/Cd
30	1.4547	0.1738	8.3661
40	1.3757	0.14229	9.6243
50	1.2907	0.1138	11.3368

4.4.1 Wind Tunnel

Experimental work in a wind tunnel is a crucial aspect of aerodynamic research and development, allowing engineers and scientists to study the behavior of aircraft components, such as winglets, under controlled airflow conditions. Here's an overview of how experimental work in a wind tunnel can be conducted for evaluating winglets:

Begin by preparing the winglet prototypes, ensuring they accurately represent the intended design, including any corrugations. Mount the winglet prototypes onto a model of the aircraft wing or a test rig within the wind tunnel. Install instrumentation such as

pressure taps, force sensors, and flow visualization devices on and around the winglets to collect data during testing. Define a test matrix outlining the various test conditions and parameters to be investigated. This may include angles of attack, airspeeds, Reynolds numbers, and winglet configurations. Ensure the test matrix covers a range of operating conditions relevant to the intended application of the winglets.

Set up the wind tunnel to replicate the desired airflow conditions, including airspeed and turbulence levels. Calibrate the instrumentation to ensure accurate measurement of aerodynamic forces, pressures, and flow characteristics. Conduct baseline tests without the winglets to establish a reference for comparison. Collect data during wind tunnel testing using the installed instrumentation. Measure aerodynamic forces (lift, drag, and side force) acting on the winglets using force balances or load cells. Record pressure distributions on the winglets using pressure taps or pressure-sensitive paint. Capture flow visualization images or videos to observe airflow patterns, separation points, and vortex shedding around the winglets.

Analyze the collected data to evaluate the aerodynamic performance of the winglets under different test conditions. Compare the results with the baseline tests and theoretical predictions to assess the effectiveness of the winglets in reducing drag, controlling vortices, and improving lift-to-drag ratio. Identify any areas of improvement or optimization based on the experimental findings. Validate the experimental results by comparing them with computational simulations or theoretical models. Use the insights gained from the experimental work to refine the design of the winglets or explore alternative configurations. Iterate the testing process as needed to investigate specific aspects or refine the understanding of the winglet's aerodynamic behavior.

Document the experimental procedures, test results, and analysis findings in a comprehensive report. Provide clear explanations of the methodology, results, and conclusions drawn from the experimental work. Share the findings with stakeholders, collaborators, or the broader scientific community through presentations, publications, or technical reports by conducting experimental work in a wind tunnel, researchers can gain

valuable insights into the aerodynamic performance of winglets and make informed decisions to optimize their design for improved efficiency and performance in real-world applications.



Fig:4.9 : Testing in wind tunnel

4.4.2 Numerical Simulation

Computational Domain: A numerical solution in computational fluid dynamics (CFD) must be the area of place for which current was modelled. This is a variational three-dimensional structure made up of a limited amount of tiny simulation units, or pieces. The structure of all the issues under investigation as well as the boundaries and constraints placed on the movement establish the governing equations.

Numerical Simulation: This method of quantitatively simulating a challenge or utilizing a supercomputer to provide an approximation of a response, involves employing algebraic calculations and methods to resolve an issue. Computer modelling for CFD entails discretizing the mass transfer similarity transformations into a collection of mathematical formulas that may be resolved numerically.

Discretization: Utilizing computational tools like discretizing, relatively fixed volumes, or structural analysis approaches, the analytical solutions of heat transfer are partitioned into mathematical expressions. In order to achieve this, the simulation must be divided into fewer components, with the solutions towards the calculations of every component being approximated.

- Solution: Utilizing action is performed as well as the Gauss-Seidel, Jacobi, or conjugate gradient approaches; the problem of basic functions is simply calculated. This platform also offers answers for discontinuous places inside the finite element model where liquid parameters like speed, stress, and heat are present.
- Post-processing: By understanding the behaviour of a heat transfer, each simulation's findings were evaluated as well as visualized. The above entails computing large amounts like drag or elevated pressures as well as creating visualization tools of a fluid domain, including flow speed or contours.

The amount of data involved in a finite element model, the quantitative measures taken, as well as the accessible computing infrastructure, all affect how accurate and effective theoretic calculations are in CFD. Simulators have uses throughout numerous sectors, especially in the aircraft and automobile industries, as well as in bioengineering.

4.5 Fabrication of Wing in 3D Printing

4.5.1 Fabrication Method

They are alternative power sources that deliver power by using the air's velocity. These are made up of a few parts, such as centers, engines, and propellers. Finding increasingly economical and environmentally friendly methods for generating wing power is necessary given the rising desire for environmentally friendly power. 3D printing is indeed a possible machining operation for wings.

The method of 3D printers, sometimes referred to as prototyping, involves adding substance one section at a time to produce 3D items. PLA is a substance that is frequently used in fabrication because of its affordability, usability, and biocompatibility.

- There are various phases involved in creating wing parts utilizing 3D printing and polylactic acid material, including Design: Utilizing CAD software, the materials are first designed before being 3D printed. The part is created as a 2D image, which is later transformed into a folder that the printer can read.
- 3D printing: After the layout has been completed, the element is 3D printed utilizing polylactic acid substance. In accordance with the requirements, the 3D printing technology warms the polylactic acid and ejects it step by step. According to the dimensions and complexities of the element, this procedure could take hours to complete.
- Post-processing: This element may need post-processing to enhance both its structural qualities and its external polish once it's been 3D manufactured.
Methods for post-processing could involve sandpaper, spraying, or finishing.
- Assembling: The last stage in creating a finished from the 3D-printed parts. This entails putting it in, mounting the structure and engine, and joining the propellers towards the center.

In summary, producing wing parts utilizing manufacturing and polylactic acid is a feasible and affordable method of producing sustainable power equipment. The innovation of massive wings does have the ability to make a difference in how we produce renewable energy sources, even though expanding it could pose problems.



Fig:4.10 : Fabricated Wing with Normal Winglet

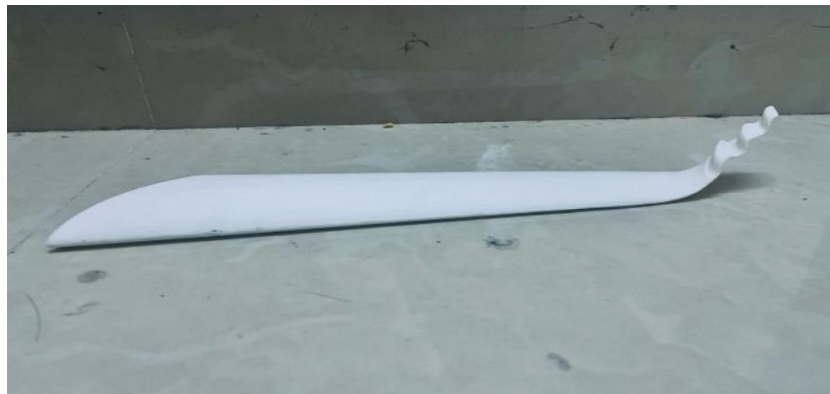


Fig:4.11 : Fabricated Wing with Corrugated Winglet

4.5.2 3D-Printing in PLA

3D printing, also known as additive manufacturing, is an innovative manufacturing technology that creates three-dimensional objects by adding material layer by layer. This process is fundamentally different from traditional subtractive manufacturing methods, where material is removed from a solid block to create a part.

Micro turbojet engines often require complex and lightweight components with intricate geometries. 3D printing allows for the fabrication of such parts with minimal material waste, reducing the weight of the engine and improving efficiency.

3D printing offers numerous advantages, including rapid prototyping, customization, and the ability to create complex geometries that are difficult or impossible to manufacture with traditional methods. It's used in various industries including aerospace, automotive, healthcare, fashion, and consumer goods for prototyping, tooling, and end-use part production. Additionally, 3D printing is increasingly being explored for applications in areas like construction, food, and bioprinting.

Polylactic Acid (PLA) is a biodegradable thermoplastic polyester derived from renewable resources such as corn starch or sugarcane. It's one of the most commonly used materials in 3D printing due to its ease of use, environmental friendliness, and wide availability. Here are some key properties of PLA

- **Biodegradability:** PLA is biodegradable, meaning it can be broken down by microorganisms in the environment over time. This makes it an environmentally friendly option compared to traditional plastics derived from fossil fuels.
- **Ease of Printing:** PLA is relatively easy to 3D print compared to other materials. It has low warping and shrinkage, which minimizes the risk of print failures. PLA also adheres well to build platforms, reducing the need for additional adhesives or heated beds.

CHAPTER 5

RESULT AND DISCUSSION

5.1 VELOCITY STREAMLINE IN ANSYS

In CFD, the term "velocity profile" describes the representation of a fluid's airflow at a particular vantage point. The motion of fluid molecules throughout a liquid is depicted by speed profiles.

Users still need the outcomes of dynamic CFD simulations in order to build speed profiles in ANSYS. The speeds are produced by ANSYS using the angular momentum information that has been gathered from the experiment. The methods to construct speed flow patterns in ANSYS are as follows:

- Build or export the flowing area structure.
- Established ANSYS to simulate liquid motion.
- To collect the speed data, we performed simulations.
- From the set of possible charts in the CFD article system, choose "Speed Flows."
- Set the parameters for the speed vortices plot, including the color, thickness, and quantity of streamlining to be shown, as well as the streamlines' beginning positions.
- Create a graph of speed streamlines.

When the speed enhancement chart has been created, users are able to employ it to see how the current is flowing at a specific moment in time. The concentration of the velocity profile reveals the flow velocity, and those who depict the route that liquids take are those who keep moving throughout the liquid. You may learn more about the behavior of the

fluids and spot areas of greater or moderate speed, roughness, as well as other movement characteristics, by looking at the speed profiles.

The statistics of the speed optimization in ANSYS offer important new perspectives on how the fluid under simulation behaves. It is feasible to spot zones of roughness, locations of elevated or decreased speed, or those stream characteristics by observing the track that vortices take as they pass inside the stream.

The speed contours in ANSYS could produce the following expected targets:

- Flowing characteristics: In ANSYS, the speed profiles display the heat transfer characteristics. It is easy to identify if a flow is agitated or clean and whether it contains air currents or funnels by looking at the flows.
- Speed Distribution: The concentration of the airspeed profiles provides information about the wind's direction. Zones with significant process frequency is those with a high velocity, whereas locations with a lower workflow volume are those with a lower speed.
- Division of flows: The region of turbulence, in which the material, can be found using the speed profiles. Area of lower tension and greater drag may result from this.
- Areas of recirculation: The material is bouncing back upon itself streamwise, and these regions can be located using speed profiles. In certain systems, this region results in sections of movement that are stationary. to local regions of the heat transfer that may be improved to enhance efficiency by looking at the speed profiles.

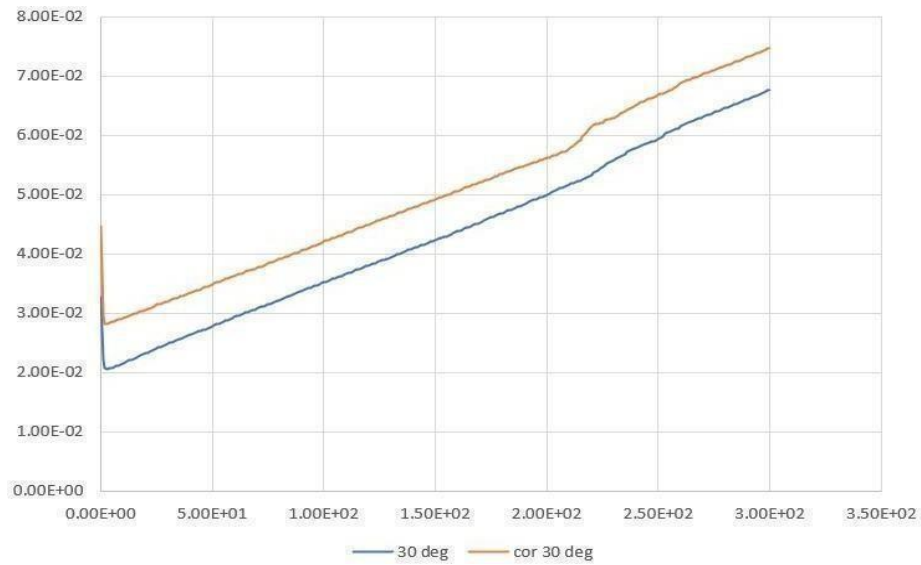


Fig:5.1 : C_l of Normal & Corrugated Winglet



Fig:5.2 : C_d of Normal & Corrugated Winglet

In conclusion, ANSYS's speed profiles offer a potent tool for understanding and visualizing liquid motion. Development teams can learn more about the behavior.

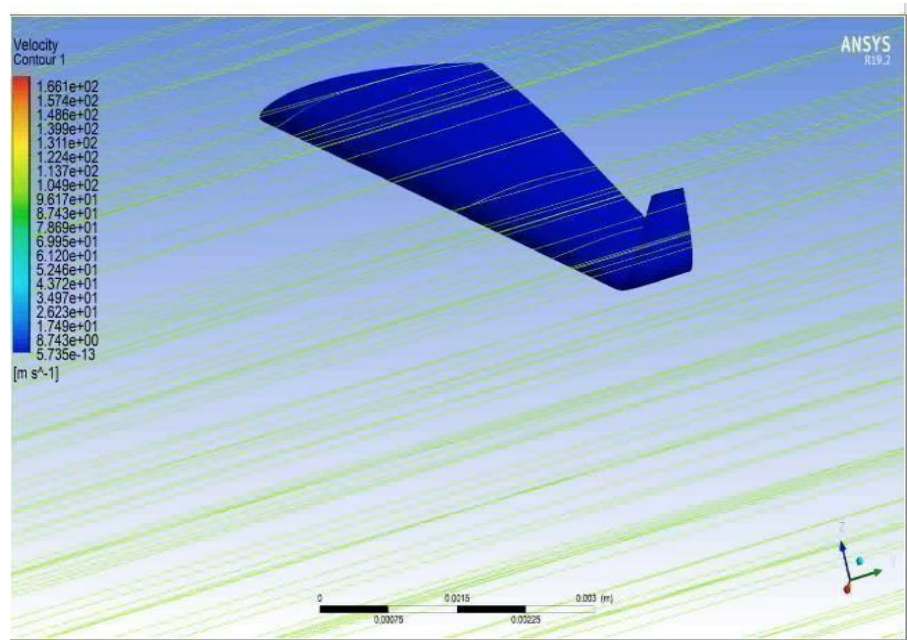


Fig: 5.3 : Velocity Streamline of Sweptback wing

Findings from the speed profile in ANSYS for a wind farm running at 0.9 airspeed and 100 revolutions per minute can reveal important details about the turbulence intensity and effectiveness of the wind farm in such circumstances. The propellers are confronted with exceptionally high gusts at 0.9 airspeed and are producing energy. The gradients throughout the propellers may be observed, and the effectiveness of the wing under these system parameters could be determined using the speed profile findings in ANSYS.

CHAPTER 6

CONCLUSION

The direction that objects take as they pass across the propeller may be seen in the profile findings, and the concentration of the trajectories reveals the wind's velocity. Around the propellers, the speed flows may exhibit a complicated airflow with a larger process concentration at 0.9 speed. This suggests that the material is flowing more swiftly everywhere in the propellers and that there could be potential elevated zones underneath. Whenever there are zones of divergence or recombination across the propellers, which may cause areas of sluggish flow and reduced efficiency, the speed profile data might also reveal those locations. Manufacturers can optimize the structure of the propellers to reduce airflow and increase power production by evaluating the streamlining data.

Also, the effectiveness of the wing at 100 revolutions per minute can be examined using the speed profile findings. The wattage of the wing below these system parameters can be calculated by analyzing the concentration of the velocity profiles and the flow behavior around the blades. The outcomes of the streamlining may also be employed to refine the propeller structure for optimum effectiveness and productivity.

In conclusion, the ANSYS speed profile findings for a windfarm at 0.9 speed and 100 revolutions per minute can give important information on the flow behavior and operation of the wing. Researchers and architects can maximize effectiveness and productivity by studying the system behavior of propellers and examining the wattage

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