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NUST COLLEGE OF
ELECTRICAL AND MECHANICAL
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DESIGN AND FABRICATION OF TRANS-WING RC PLANE

PROJECT REPORT

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ABSTRACT

Remote-controlled (RC) planes have been a popular hobby for decades, providing a fun and engaging way to learn about the principles of heavier-than-air flight. In recent years, advances in technology have also enabled the use of RC planes for a variety of other purposes, including education, defense, and even emergency response. The ability to transition between fixed-wing and rotorcraft configurations allows for a greater degree of flexibility and versatility in flight, providing a new level of excitement and challenge for aviation industry. For one, it provides greater range and endurance, enabling the plane to stay in the air for longer periods of time and cover longer distances. The development of the trans-wing plane represents an exciting opportunity for the aviation industry, as it has the potential to revolutionize the way we think about vertical lift and horizontal flight. By incorporating the trans-wing mechanism into the design of an RC plane, it is possible to create a highly versatile aircraft that can operate in a wide range of environments and situations. This requires a combination of mechanical engineering and control systems engineering, as the wings must be able to move smoothly and reliably between configurations while also being accurately controlled by the controller. Another important aspect of the trans-wing plane project is the testing and validation of the aircraft's performance. The purpose of this project is to design and build a trans-wing RC plane and evaluate its performance. The project aims to explore the capabilities and limitations of trans-wing planes, as well as identify any potential improvements or modifications that could be made to enhance their performance. This project report presents the results of the design and construction process, as well as the performance of the trans-wing RC plane. The report includes a literature review of existing trans-wing planes, a description of the materials and methods used in the project for fabrication, and a discussion of the results and implications of the work. The report concludes with a summary of the main findings of the project and suggestions for future work.

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CHAPTER 1- INTRODUCTION

The development of radio-controlled model aircraft can be traced back to the early 20th century, when hobbyists began building and flying small, remotely controlled planes as a form of entertainment. These early models were typically powered by hydrogen gas and controlled using a basic form of radio signal and were often used as a novelty act in music halls and other public venues.

Since those early days, the technology behind RC planes has advanced significantly, and today's models are highly sophisticated, capable of being flown with a high degree of accuracy and control. Modern RC planes come in a wide range of sizes and styles, from small, toy-like models to large, highly detailed replicas of real aircraft. Many RC plane enthusiasts build their own models from kits or plans, allowing them to customize and fine-tune their aircraft to their specific needs and preferences. One particularly innovative development in the world of RC planes is the concept of the trans-wing aircraft. This design, which was first patented in 2019 by a US-based company, utilizes a transverse folding wing mechanism to enable efficient vertical takeoff and landing, as well as efficient horizontal flight [1]. The trans-wing design has the potential to offer a number of key advantages over other VTOL aircraft designs, including increased range, endurance, and payload capacity.

Despite these advantages, the development and implementation of trans-wing technology is not without its challenges. As with any complex systems engineering project, careful analysis and consideration must be given to a wide range of factors, including design, testing, and safety. While the trans-wing concept is still in the early stages of development, it has already attracted significant interest from both hobbyists and industry professionals. As research and development efforts continue, it will be interesting to see the full potential of this innovative aircraft design realized. One of the key advantages of the trans-wing design is its ability to provide efficient vertical lift and horizontal flight, making it well-suited for a wide range of missions and operating environments.

Additionally, the trans-wing concept has the potential to offer increased range, endurance, and payload capacity compared to other VTOL aircraft designs, depending on the specific mission requirements. The development of the trans-wing concept is still in its early stages, and further research and development efforts will be needed to fully realize its potential. [2] However, the concept has already attracted significant interest from both hobbyists and industry professionals, and it is likely to play a significant role in the future of aviation. Trans-wing RC planes have the potential to revolutionize the field of aviation by offering improved efficiency and maneuverability. These innovative aircraft are equipped with wings that can transform their shape in flight, allowing them to optimize their aerodynamics for different phases of flight. As a result, trans-wing planes have the potential to reduce fuel consumption, increase payload capacity, and enhance stability in gusty conditions. Although trans-wing planes are still in the experimental stage, they represent a promising new technology that could have a significant impact on the future of aviation. Some of the key considerations that will need to be addressed in the development of the trans-wing aircraft include the design and implementation of the transverse folding wing mechanism, the integration of control systems and servomechanisms to enable precise control of the aircraft, and the testing and validation of the aircraft's performance in a wide range of operating conditions. [3]

Overall, the trans-wing concept represents an exciting and innovative development in the field of aviation and has the potential to revolutionize the way we think about vertical lift and horizontal flight. As research and development efforts continue, it will be interesting to see the full potential of this unique aircraft design realized.

Figure 1-1 Trans-wing RC plane

1.1 Background Knowledge

The aerodynamics of trans-wing RC planes are fundamentally different from those of traditional fixed-wing aircraft. Because it changes its wings configuration in midair. The Trans-wing RC Plane is a hybrid aircraft that combines the characteristics of a fixed-wing aircraft and a rotary- wing aircraft. [4] It is designed to have the ability to take off and land vertically like a helicopter and then transition to horizontal flight like a fixed-wing aircraft. When the wings in folded position the trans-wing will be very similar to quadcopter and the motor will give the vertical lift to the plan. During the midair the wings will changes its configuration to become straight and will give the horizontal motion to the plan. During the configuration of the wings the weight of the plane will shifted towards forward and as a result the center of gravity of the plane will also shifted from one place to other to balance the plane. This project aims to develop a remote-controlled prototype of this unique aircraft and demonstrate its capabilities.

1.2 Motivation

There are several potential benefits of the Trans-wing RC Plane which were kept in mind before development on this model begins. Few of them are as follows:

1.2.1 Improved Efficiency

The Trans-wing RC Plane has the potential to be more fuel-efficientthan traditional aircraft, as it does not require a long runway for takeoff and landing and can fly longer distances than a helicopter.

1.3 Versatility

The ability to take off and land vertically makes the Trans-wing RC Plane more versatile than traditional fixed-wing aircraft, as it can operate in areas where a runway isnot available.

1.3.1 Safety and Rescue Applications

The Trans-wing RC Plane has the potential to be safer than traditional aircraft, asit has the ability to make a controlled emergency landing in the event of an engine failure. The Trans-wing RC Plane has potential military andrescue applications, as it can be used for surveillance, reconnaissance, and search and rescue operations in places where landing area is very small for normal plane to land.

CHAPTER 2 - LITERATURE REVIEW

Trans-wing planes have the potential to offer significant benefits over traditional fixed-wing planes, such as reduced fuel consumption and increased payload capacity, but the technology is still in the experimental stage and there are many challenges to be addressed before it can be deployed on a wide scale.

Although there have been some early studies on the performance of trans-wing planes, there is a lack of comprehensive data on their aerodynamic characteristics and the mechanisms by which their wings transform. In addition, there is a need for more advanced modelling and simulation tools to help us optimize the shape and movement of trans-wing planes for different flight conditions. The goal of this project is to contribute to the development of trans-wing plane technology by addressing the following research questions:

What are the key factors that influence the aerodynamic performance of trans-wing planes? How can the shape and movement of their wings be optimized for different flight conditions? How can these optimization processes be automated and integrated into design tools?

Through a combination of experimental testing and computational modelling, we will seek to better understand the capabilities and limitations of trans-wing planes and identify opportunities for further improvement. By addressing these research questions, we hope to help advance the state of the art in trans-wing plane technology and pave the way for future developments in this exciting field.

Trans-wing RC planes have the potential to revolutionize the field of aviation by offering improved efficiency and maneuverability. These innovative aircraft are equipped with wings that can transform their shape in flight, allowing them to optimize their aerodynamics for different phases of flight. As a result, trans-wing planes have the potential to offer a number of benefits over traditional fixed-wing planes, including a smaller footprint, longer range and endurance, faster cruise speeds, greater payload capacity, and greater agility.

2.1 Smaller Footprint

One of the key advantages of trans-wing planes is their smaller footprint. Because they are able to take off and land vertically, they do not require the same amount of ground support equipment or landing area as other aircraft with similar wingspans. [5] This makes them particularly well-suited for use in urban or other confined environments where space is at a premium.

2.2 Longer Range/Endurance

Another benefit of trans-wing planes is their longer range and endurance. By minimizing the time spent in the take-off and landing phases of flight, and by eliminating the extra weight and drag of separate propulsion systems for these phases, trans-wing planes can achieve increased efficiency. [6] In addition, the option of higher-aspect wings and the ability to optimize wing shape for different flight conditions can further improve their range and endurance.

2.3 Faster Cruise

Trans-wing planes are also capable of faster cruise speeds due to their clean, aerodynamic airframes and propulsors that are used for all phases of flight and attached rigidly to the wing. The option of higher wing loading can also contribute to faster cruise speeds.

2.4 Greater Payload

Furthermore, trans-wing aircraft possess a myriad of advantages, including enhanced payload capacity and heightened maneuverability in comparison to conventional fixed-wing counterparts.

2.5 Greater Agility

By folding their wings vertically for takeoff and landing, trans-wing planes are less susceptible to vertical gusts and turbulent air, which can improve their stability and control during these phases of flight [7]. To make a trans-wing RC plane, a thorough understanding of airplane lift, drag, upthrust, and airfoils is required. Detailed research on the design of planes and the various phenomena that occur during flight will also be necessary. An understanding of aerodynamics is crucial for designing a stable plane and ensuring that the entire structure is correctly configured.

CHAPTER 3 - DESIGN METHODOLOGY

3.1 CAD Model

The Trans-wing RC aircraft design was developed utilizing the SOLIDWORKS computer-aided design (CAD) software program. The design process was approached systematically, beginning with the identification of the problem and the establishment of design criteria. The design was then created in SOLIDWORKS by first creating a new part file with appropriate units and dimensions, and utilizing sketching tools to develop 2D profiles and shapes that were used to generate 3D models via extrusion, revolution, and loft features. Additional design features were incorporated utilizing the Hole wizard tool to create holes and the cut-extrude tool to create cuts and openings in the model. The mirror and pattern features were utilized to create symmetry and repetition in the design.

Various components such as the motor, slider mechanism, and hinge were designed and imported as external references to the model. The move and rotate tools were utilized to position these components, and the mates feature was used to constrain them in the appropriate positions and orientations. Dimension and annotation tools were also utilized to add dimensions and labels to the model, and the configurations feature was utilized to create different variations of the design.

To ensure the functionality and reliability of the power kit, simulation and analysis tools were employed, including the motion study, Fluent analysis, stress analysis, and fatigue analysis. The results of these analyses were utilized to refine the design and optimize the performance of the Trans-wing RC aircraft.

3.2 Fuselage

The fuselage of the Trans-wing RC aircraft was designed utilizing SOLIDWORKS CAD software. The design process commenced with the creation of a new part file with appropriate units and dimensions. Sketching tools were utilized to develop 2D profiles, curves, and shapes for the fuselage, which were subsequently lofted and revolved to generate a 3D model. The extrude cut command was also employed to create openings and internal structures for the fuselage. Upon completion of the design process, the final fuselage design was exported as a 3D model file. The utilization of SOLIDWORKS and the before mentioned commands facilitated the design and development of the Trans-wing RC aircraft fuselage with high efficiency and accuracy.

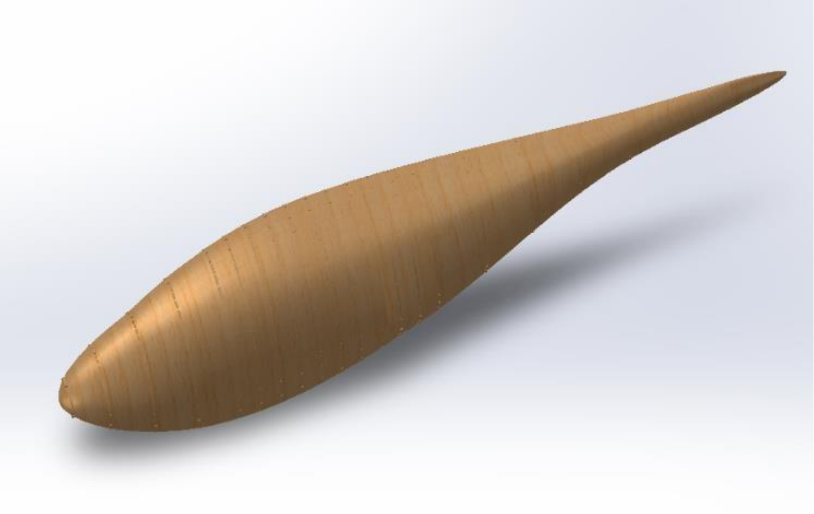


Figure 3-1: Internal Structure of Fuselage

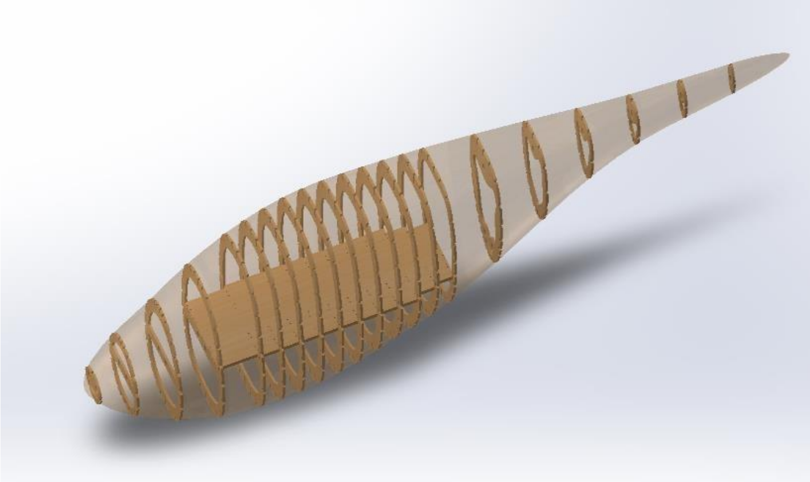


Figure 3-2: 3D Model Fuselage of Trans-wing RC plane

3.3 Wings

The wings were created using a combination of sketching, extrusion, features to generate the 3D model. The extrude cut command was used to create openings for the hinge and other electrical components. The wings was also designed to accommodate the motors, which were imported as external references and positioned using the move and rotate tools. These are the movable portions of wings.

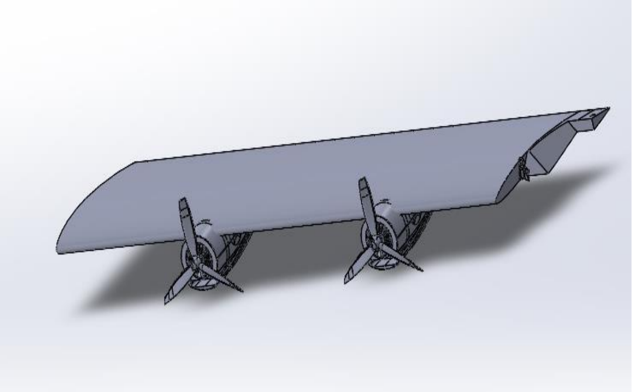


Figure 3-4: 3D model of left side of the wing

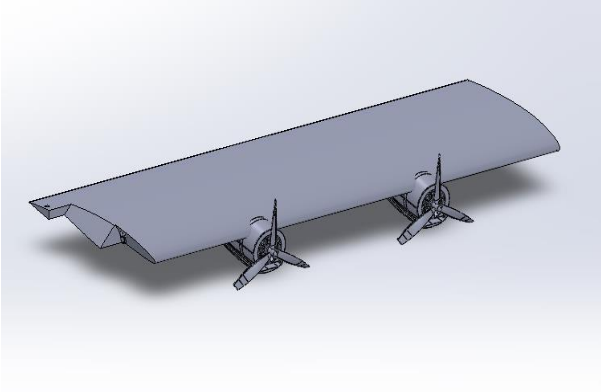


Figure 3-3: 3D model of right side of the wing

Once the wings model was complete, it was imported into an assembly file and the various components, such as the motors and propellors, were added and positioned using the move and rotate tools. The mate's feature was used to constrain the components in the appropriate positions and orientations.

3.4 Hinge Design

The design process of a hinge for the wings was an incredibly critical and challenging task, as it required careful consideration to ensure that the hinge could effectively support the entire load of the wings during transition. Additionally, the hinge needed to provide two planar motions simultaneously as the wings transitioned. After numerous rounds of experimentation and iteration, a final design was achieved as shown.

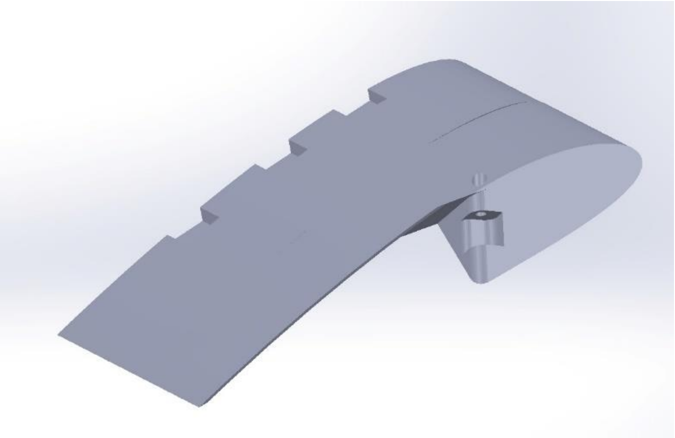


Figure 3-5 Left Side of Hinge

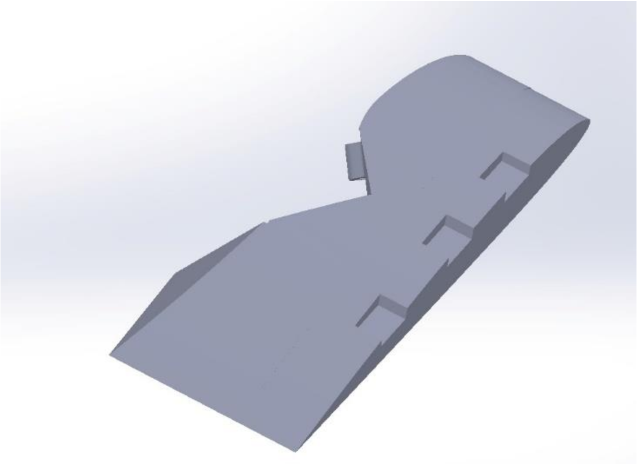


Figure 3-6 Right Side of Hinge

The initial step in the design process involved determining the appropriate angles at which the hinge should be set. The first consideration was the angle with respect to the **vertical z-axis** for the wing cut. Extensive analysis and testing led to the conclusion that a **48-degree** angle would provide the necessary support and stability for the wings during their transition. This angle was chosen to optimize the distribution of the load and ensure that the hinge could handle the forces exerted on the wings. Furthermore, the hinge also needed to accommodate a **35-degree angle** with respect to the **y-axis**. This angle was carefully selected to allow for the desired planar motion of the wings during their transition. By aligning the hinge in this manner, the wings could smoothly and efficiently move in two directions simultaneously, enabling the desired flight characteristics.

To ensure a seamless integration of the hinge with the wing structure, an additional consideration was made for the alignment of the hinge. It was decided that a slanted cut would provide the most suitable alignment, allowing for optimal contact and engagement between the hinge components. This alignment would not only facilitate smooth motion but also enhance the overall strength and durability of the hinge assembly.

With the angles and alignment determined, the design team proceeded to develop detailed plans and specifications for the hinge. This involved considering factors such as material selection, manufacturing processes, and assembly techniques. High-strength materials were chosen to withstand the immense forces experienced during wing transition, and advanced manufacturing techniques were employed to ensure precision and reliability. Throughout the design process, extensive simulations and prototyping were conducted to validate the performance and functionality of the hinge design. Finite element analysis was used to evaluate the stress distribution and identify any potential weak points or areas of concern. Adjustments and refinements were made iteratively, incorporating lessons learned from each testing phase.

The result of this meticulous design process was a hinge that met all the required criteria. It could successfully support the full load of the wings during transition, provide simultaneous planar motion, and maintain structural integrity under extreme conditions. The design team's dedication, attention to detail, and commitment to excellence resulted in a hinge that played a crucial role in the overall functionality and performance of the wing system.

3.5 Mechanism Design

In our pursuit of enhancing the functionality and versatility of our model, we have developed and implemented two distinct mechanisms. These mechanisms were meticulously designed and carefully selected to augment the capabilities of our model. The first mechanism we devised is the slider mechanism, while the second one involves servo motors with retractable gears.

3.5.1 Slider Mechanism

The model of slider is externally imported from the internet when the threaded shaft rotates with the help of motor as a result the bar will move forward and backward that is actually directly linked with the wings to transform in order to show the 2 degree of freedom motion. The mechanism being utilized in this scenario is a slider motion, which involves a slider moving back and forth along a fixed path. This motion is achieved through the rotation of a threaded shaft in both clockwise and counterclockwise directions.

Attached to the slider are rods which are connected to wings. As the slider moves back and forth along its path, the rods push and pull the wings, causing them to move up and down or back and forth, depending on the desired motion. This type of mechanism can be useful in a variety of applications, such as in manufacturing processes, robotics, or even in the movement of certain types of machinery. The slider motion allows for precise and controlled movement of the wings or other components, making it a reliable and effective solution for many different scenarios.

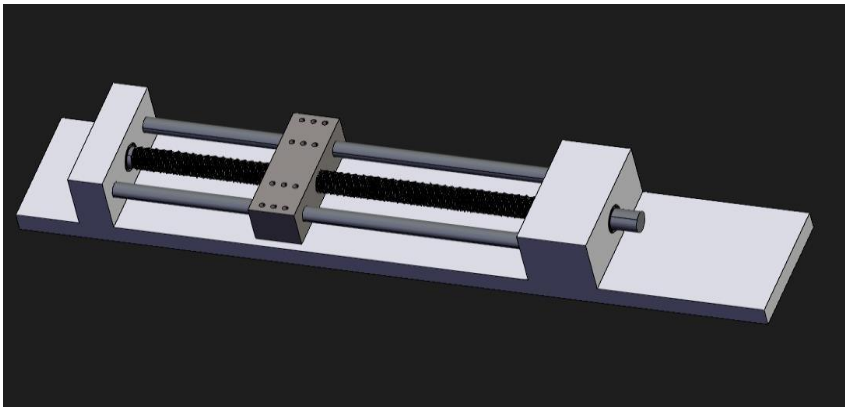


Figure 3-7: 3D Model of slider Mechanism

3.5.2 Servo Motors with retractable gears

On the other hand, our implementation of servo motors with retractable gears introduces a dynamic and efficient means of achieving rotational motion. These servo motors are equipped with specialized gears that can be extended or retracted as needed. This unique design allows for increased torque and improved control over rotational movements. However, during practical testing and transition phases, we have encountered a specific challenge related to this mechanism. It was observed that the drag generated by the retracting gears could exert a significant force on the wings of our model. This became evident due to the interconnected nature of the wings and the servo motors via connecting rods. As the gears retract, the resulting drag force has the potential to push the wings back.

This unintended consequence poses a potential obstacle to the smooth operation of our model. The pushing back of the wings can adversely affect the stability and balance of the model, compromising its overall performance. To address this issue, we are actively exploring several solutions and modifications to minimize the drag force and mitigate its impact on the wing position.

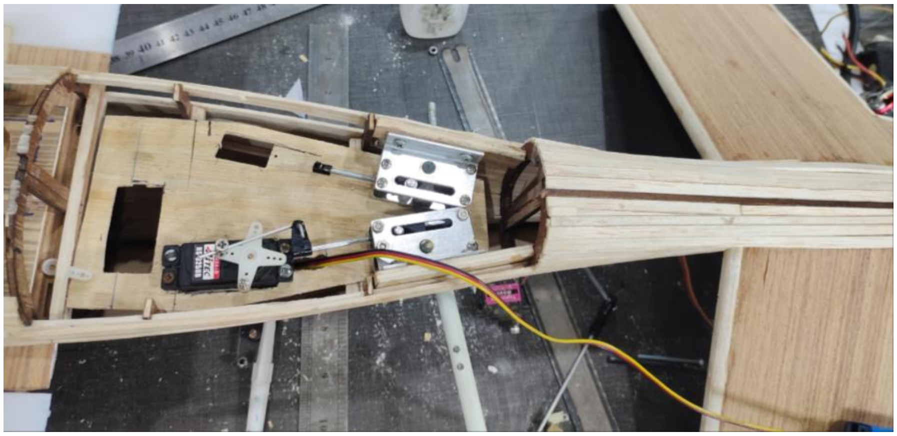


Figure 3-8: Servo Mechanism with Retractable Gears

3.5 Complete Assembly

The final assembly of the Trans-wing RC plan has been meticulously created in SolidWorks software. The fuselage was taken as base model and all other components were imported into an assembly file and positioned using the move and rotate tools. The mate's feature was used to constrain the components in the appropriate positions and orientations, and to ensure that the wings can show transformation smoothly and reliably.

The entire process, from conception to completion, has been carefully planned and executed to produce a flawless final product. The CAD model is an accurate representation of the physical plane, with all of its features and components fully realized in digital form.

The SolidWorks software used to create the model is a powerful and sophisticated tool that allows for the precise modeling of complex 3D objects. The design of the trans wing plane required careful attention to detail, with a focus on creating a robust and reliable aircraft that could withstand the rigors of flight. The software allowed the designers to test and refine the model before construction, ensuring that the final product would meet the highest standards of performance and safety.

The completed model is a stunning example of modern engineering, with its sleek lines and intricate details. The digital model can be rotated and viewed from any angle, allowing for a detailed examination of every aspect of the plane's design. The model includes all of the necessary components, such as the fuselage, wings, tail, landing gear, and propulsion system, with each part designed to fit together perfectly.

The final renderings of the Trans-wing RC plan provided a clear and detailed representation of the design and allowed us to showcase the various features and components of the product.

Overall, the use of SOLIDWORKS and 3DMax enabled us to create a functional and visually appealing assembly of the Trans-wing RC plane.

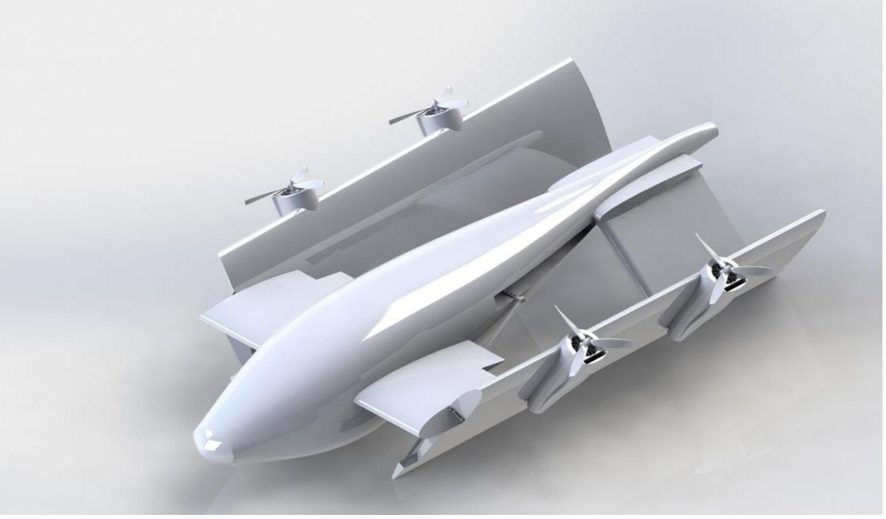


Figure 3-9: Initial Phase of transition

The slider mechanism is designed to enable backward and forward movement, which in turn causes the rods connected to the wings to move back and forth accordingly. During the transition of the wings, an intermediate state is reached where the wings are slightly folded. This state is critical as it marks a shift in the center of gravity, causing it to slightly move forward. The movement of the center of gravity is an important consideration in aircraft design, as it affects the overall stability and handling of the aircraft.

Once the slider mechanism is completely moved back, the wings are fully folded, resulting in a significant change in the position of the center of gravity. It is crucial to carefully manage this transition in order to maintain the balance and stability of the aircraft during flight. The use of advanced technology and precise engineering ensures that these transitions are executed seamlessly, allowing for safe and efficient flight operation.

Figure 3-10: Second Phase of transition

Figure 3-11: Completed Transition View

3.6 Airfoils in general

An airfoil is the cross-section of a wing. It is used when calculating the lift generated by the wing and to show the airflow around the wing. When describing the shape and size of an airfoil, normal units are not used. [8] Instead, it uses dimensioning relative to itself. The most important aspects of an airfoil for airplanes is its AOA, camber (in % of the chord) and the placement of the maximal camber thickness. The airfoils that sailplane often use are usually referred to as thermal duration airfoils, meaning they make use of thermal columns to extend their flight time. [9]

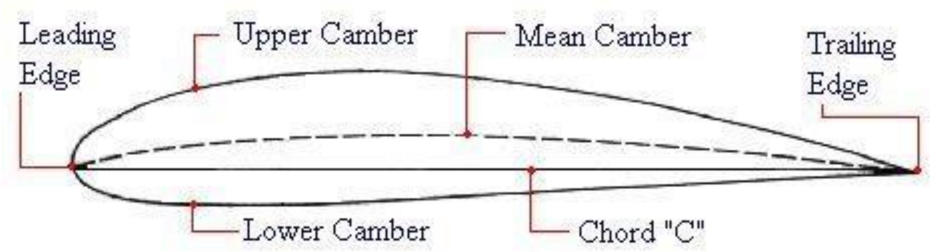


Figure 3-12: Basic Parameters of Airfoil

3.7 Airfoils of choice

The wings are probably the most important aspect of this report. Its design will directly correspond to the distance the UAV will be able to glide. The data for the airfoils this report will cover will be taken from the software which will consist of Airfoil Tools.

3.7.1 CAL4014l (CLARK YH)

The CAL4014l is a reflexed flying-wing airfoil, which means that the trailing edge is deflected slightly upwards. It has a wide lift range, a generous thickness and predictable stall characteristics. [10] This makes the CAL4014l a great all-purpose airfoil.

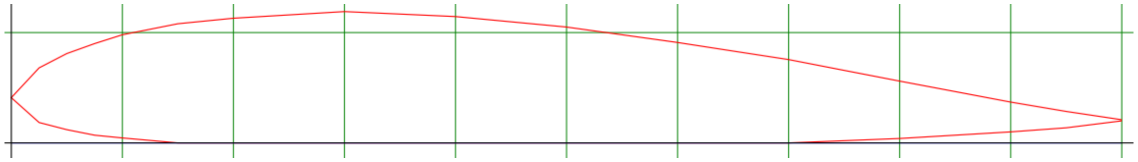


Figure 3-13: CAL40141 Airfoil

3.7.2 NACA 4301 2A

The NACA 4301 2A is used on the one seat, mid-wing Schweizer SGS 1-26 glider and the two seated, high-wing Schweizer SGS 2-33 and has proved to be successful in both models. [11]

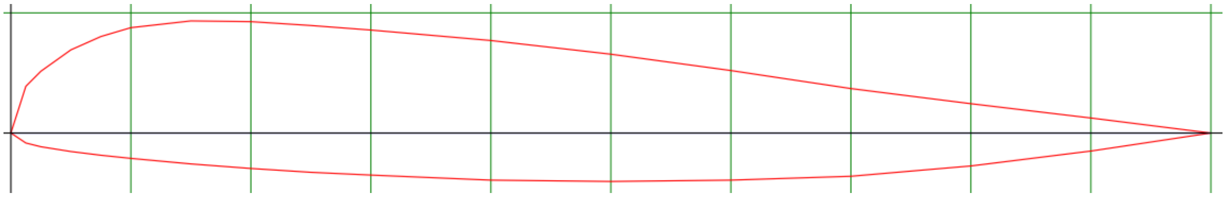


Figure 3-14: NACA 4301 2A

3.7.3 S1223

The S1223 has been extensively tested in different reports of low speed airfoils. It is able to obtain very high cL,max (about 2.2) in the absence of slats or flaps because the design favors aft loading. It has a high drag, but a very high lift too, which makes it interesting to look at.

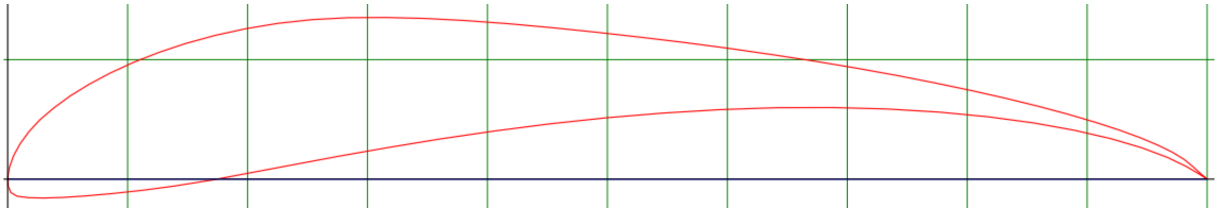


Figure 3-15: S1223 Airfoil

3.7.4 RG15

The RG15 is an interesting airfoil in that it is a F3B (the Formula-1 for sailplanes) airfoil and by that, it has a lower lift compared to the other thermal duration airfoils, which sailplanes often use, but still works better thanks to it having better performance in both speed and duration tasks, which directly corresponds to its list-to-drag ratio.

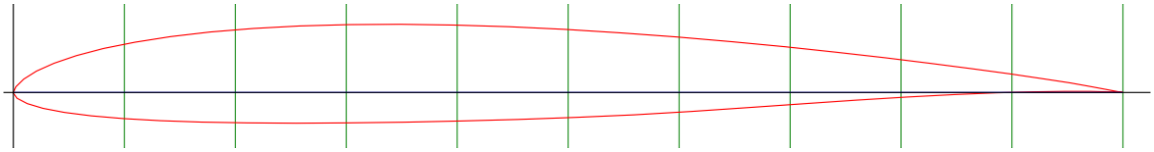


Figure 3-16: RG15 Airfoil

3.7.5 NACA 2412

It is a symmetrical airfoil with a camber of 2% and a thickness-to-chord ratio of 12%. The NACA 2412 airfoil is widely used in aircraft and wind turbine blade design due to its favorable lift-to-drag characteristics and its ability to generate high lift at low angles of attack. The airfoil's symmetric shape and low camber make it suitable for applications that require both positive and negative lift, such as in airplanes and helicopters. [12]The NACA 2412 airfoil has become a standard airfoil for general aviation aircraft, as well as unmanned aerial vehicles and wind turbines.

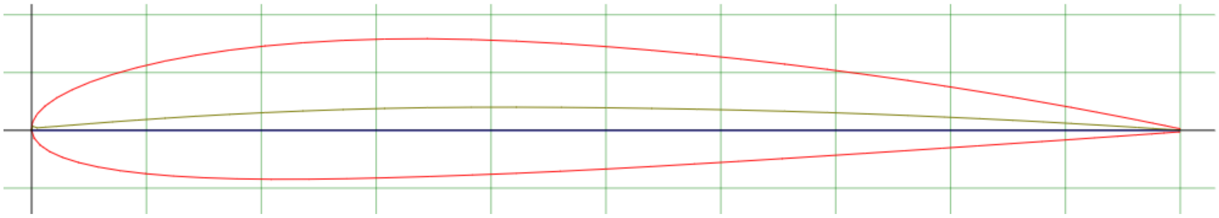


Figure 3-17: NACA 2412 Airfoil

After careful considerations and discussion, we decided to go with NACA 2412 as this is the most ideal and optimal airfoil for our project. Therefore, in the next chapter a detailed analysis is done on NACA 2412 and different variations are shown at different angles of attacks.

CHAPTER 4 - DESIGN ANALYSIS

4.1 Air Foil

The purpose of Computational Fluid Dynamics (CFD) analysis on ANSYS is to unlock the hidden mysteries of fluid flow and gain invaluable insights into complex engineering problems. With its immense computational power and advanced modeling capabilities, ANSYS CFD analysis serves as a gateway to a virtual realm where the behavior of fluids becomes tangible and comprehensible. It empowers them to scrutinize the flow behavior around intricate geometries, optimize designs, predict performance, and uncover unforeseen phenomena that are otherwise elusive in the real world. With a focus on the airfoil, we delve into the realm of flow behavior at various angles of attack, unraveling the secrets of lift, drag, and stability. Through meticulous CFD simulations, we investigate the intricate interactions between the airfoil shape, the incident airflow, and the resulting aerodynamic forces, aiming to optimize performance and enhance flight characteristics. Additionally, our analysis extends beyond the airfoil to encompass the fuselage, a vital component of the trans-wing configuration. By examining the fuselage's impact on drag, stability, and maneuverability, we gain a holistic understanding of the overall aircraft performance. This comprehensive analysis not only hones our skills in CFD simulation and ANSYS proficiency but also contributes to the advancement of trans-wing aircraft design, offering insights that could pave the way for future innovations in this exciting field. Through this project, we combine our passion for aviation with the power of computational analysis, propelling us towards a future where novel aircraft configurations hold the potential to revolutionize the skies.

4.2 Methodology

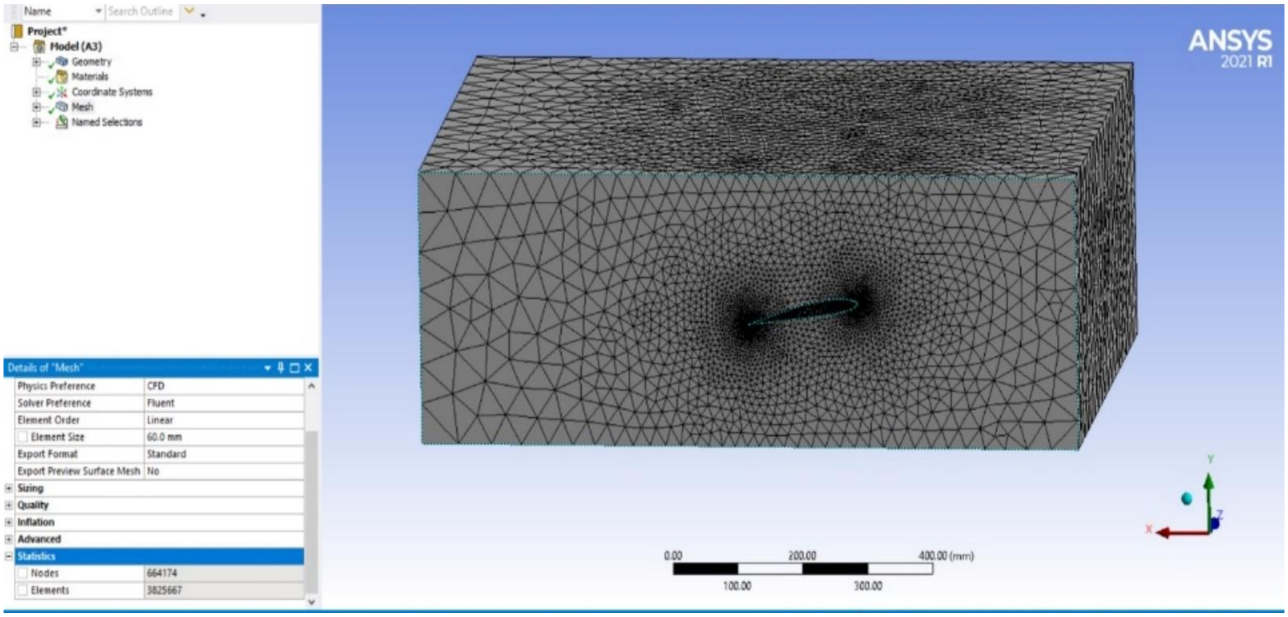
In our quest to delve into the intricate dynamics of fluid flow, we embark on a detailed CFD analysis using ANSYS, with a specific focus on a trans-wing RC plane. To simulate the real-world conditions, we set the air velocity at a constant **10 m/s**, allowing us to study the behavior of the aircraft under representative airflow conditions. The analysis commences by defining the inlet boundary condition as a velocity inlet, providing a consistent and controlled airflow into the computational domain. On the other hand, the outlet boundary condition is set as a pressure outlet. For the purpose of simplicity, we employ the simple method for our analysis, leveraging its efficiency in capturing essential flow characteristics while minimizing computational resources. Once the model is meshed, we opt for a simple second-order upwind scheme as the solving method, striking a balance between accuracy and computational cost. Additionally, to accurately capture the effects of turbulence and viscosity, we select the **SST k-omega model**, renowned for its ability to handle complex flow phenomena with high accuracy. By incorporating these choices into our analysis, we strive to generate insightful results and gain a comprehensive understanding of the aerodynamic behavior of the trans-wing RC plane.

4.2.1 Fluid Domain

In order to conduct our comprehensive CFD analysis on the trans-wing RC plane, we define the fluid domain and establish the appropriate mesh sizes. The fluid domain is configured with dimensions that reflect the physical characteristics of the aircraft. Along the positive x-axis, the domain spans 540 mm, while along the negative x-axis, it extends for 340 mm. The y-axis accommodates a distance of 170 mm in both positive and negative directions, while the z-axis covers 200 mm in both positive and negative directions. These dimensions ensure that the fluid domain adequately encapsulates the region of interest surrounding the trans-wing RC plane.

To ensure accurate representation of the airfoil and capture the flow characteristics in its vicinity, we set a specific mesh size for the airfoil face. The total mesh size of fluid domain is 60mm. The mesh size of air foil 15 mm. By this, we are able to achieve a fine resolution that captures the intricacies of the airfoil's geometry and facilitates accurate simulation of flow behavior around it. This finer mesh size on the airfoil face allows for more detailed analysis of aerodynamic forces and phenomena associated with the airfoil, thus providing valuable insights into its performance.

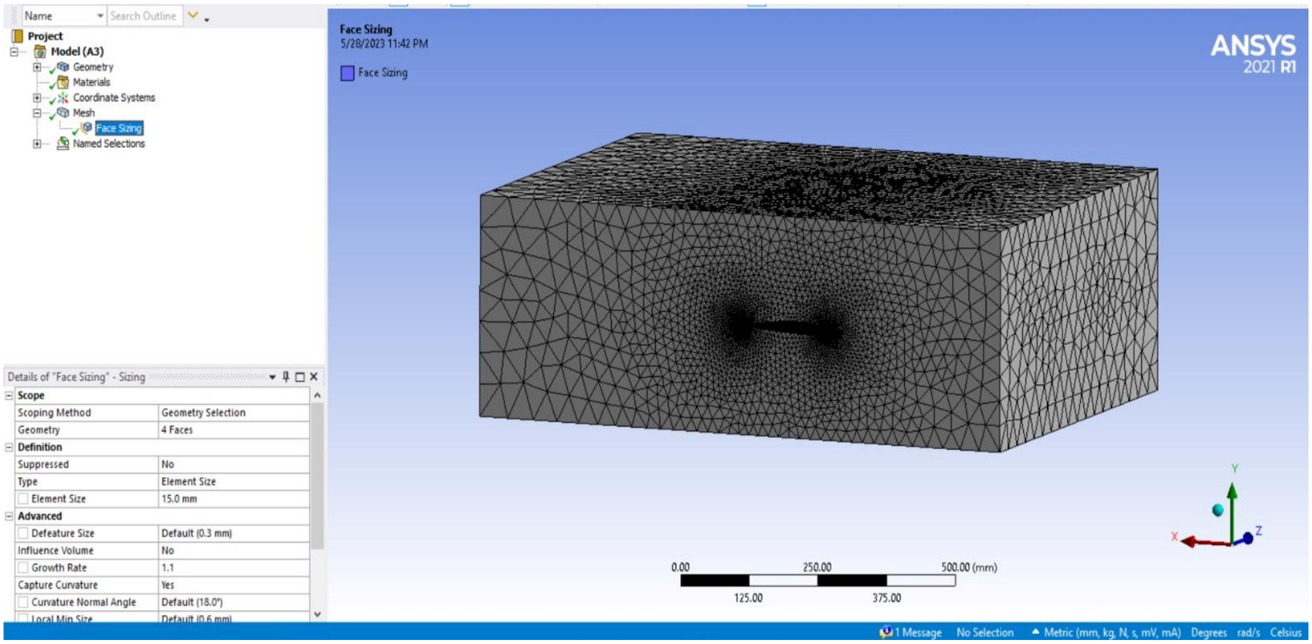
By establishing these dimensions and mesh sizes, we lay the foundation for a meticulous CFD analysis, enabling us to delve into the intricacies of fluid flow around the trans-wing RC plane and gain a comprehensive understanding of its aerodynamic behavior.



Details of "Mesh"

Physics Preference	CFD
Solver Preference	Fluent
Element Order	Linear
☐ Element Size	60.0 mm
Export Format	Standard
Export Preview Surface Mesh	No
Sizing	
Quality	
Inflation	
Advanced	
Statistics	
☐ Nodes	664174
☐ Elements	3825667

Figure 4-1: Mesh Sizing of fluid Domain



Details of "Face Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Suppressed	No
Type	Element Size
☐ Element Size	15.0 mm
Advanced	
☐ Defeature Size	Default (0.3 mm)
Influence Volume	No
☐ Growth Rate	1.1
Capture Curvature	Yes
☐ Curvature Normal Angle	Default (18.0°)
☐ Local Min Size	Default (0.6 mm)

Figure 4-2: Mesh Size of Airfoil

4.3 NACA 2412 analysis at different angles of attacks

In our rigorous CFD analysis, we focused on the renowned NACA 2412 airfoil, conducting simulations at various angles of attack to comprehensively evaluate its aerodynamic performance. To establish a benchmark for comparison, we utilized the reliable standards provided by NASA.

By employing the NASA-provided data as a reference, we aimed to verify the accuracy and reliability of our simulation results and gain valuable insights into the airfoil's behavior under different flow conditions. To validate our simulation results, we diligently compared them against the established standards provided by NASA. This involved examining key parameters such as lift coefficients, drag coefficients, and pressure distributions along the airfoil surface. By quantitatively assessing the agreement between our simulation results and the NASA standards, we could ascertain the accuracy of our CFD analysis and establish the reliability of our methodology.

The comparison of our results with the NASA standards not only serves as a validation step but also provides insights into potential discrepancies and areas for improvement. Any deviations or variations between the simulated data and the reference standards can highlight important nuances and shed light on the underlying physics that may require further investigation or model refinement.

4.3 Zero Degree Angle of Attack

During our analysis on the NACA 2412 airfoil at a zero angle of attack, we obtained compelling results in terms of lift and drag forces. The simulation revealed a lift force of 13.5 N, showcasing the ability of the airfoil to generate significant upward forces in the absence of any angle of attack. Simultaneously, the drag force was calculated to be approximately 1.2 N, indicating the resistance experienced by the airfoil in the direction opposite to the fluid flow. These outcomes provide valuable insights into the aerodynamic performance of the NACA 2412 airfoil under specific operating conditions and serve as a foundation for further optimization and design considerations in our ongoing project. In this case the ratio $\frac{\boldsymbol{L}}{\boldsymbol{D}}$ comes out to be about **11.5**.

In Computational Fluid Dynamics (CFD) analysis, pressure contours and velocity contours are visual representations of the pressure and velocity fields, respectively, within a fluid domain.

Pressure contours display the distribution of pressure values across the fluid domain. They are represented by a series of lines or filled regions that connect points of equal pressure. Each contour line or region represents a specific pressure value, and the spacing between the contours indicates the magnitude of the pressure gradient. Velocity contours represent the distribution of fluid velocities within the domain. Similar to pressure contours, velocity contours consist of lines or filled regions that connect points of equal velocity magnitude. Each contour line or region represents a specific velocity value, and the spacing between the contours indicates the magnitude of the velocity gradient.

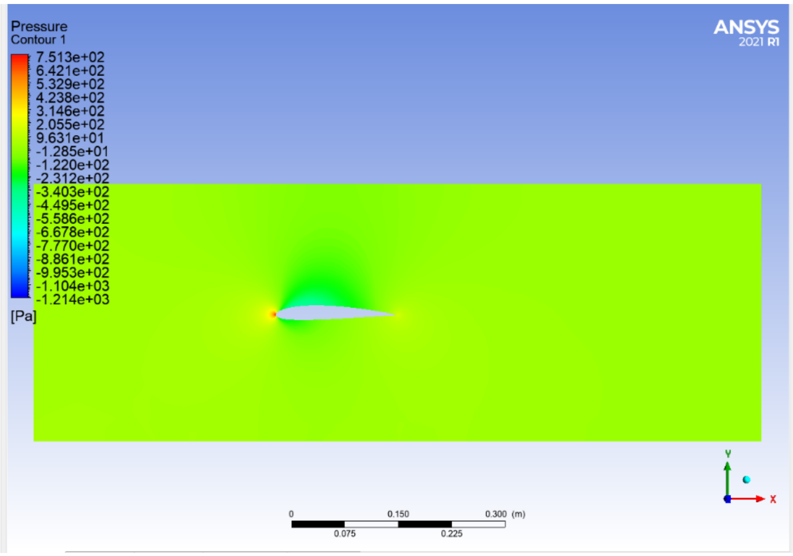


Figure 4-3: Pressure Contour

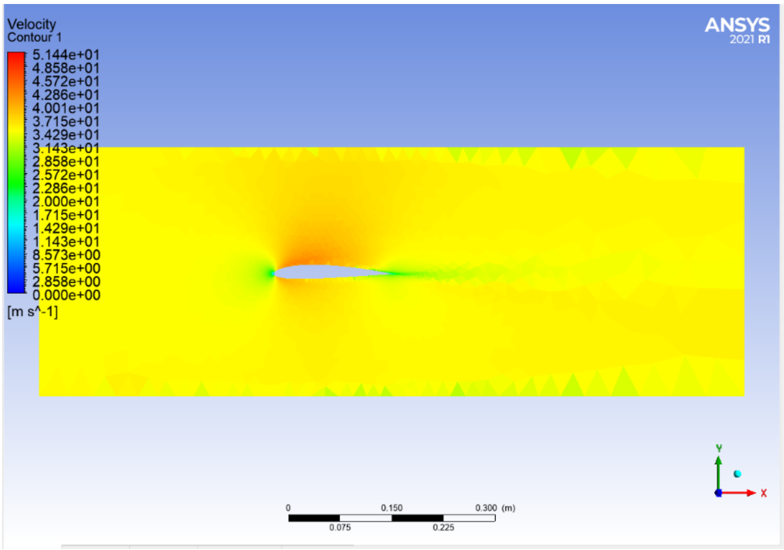
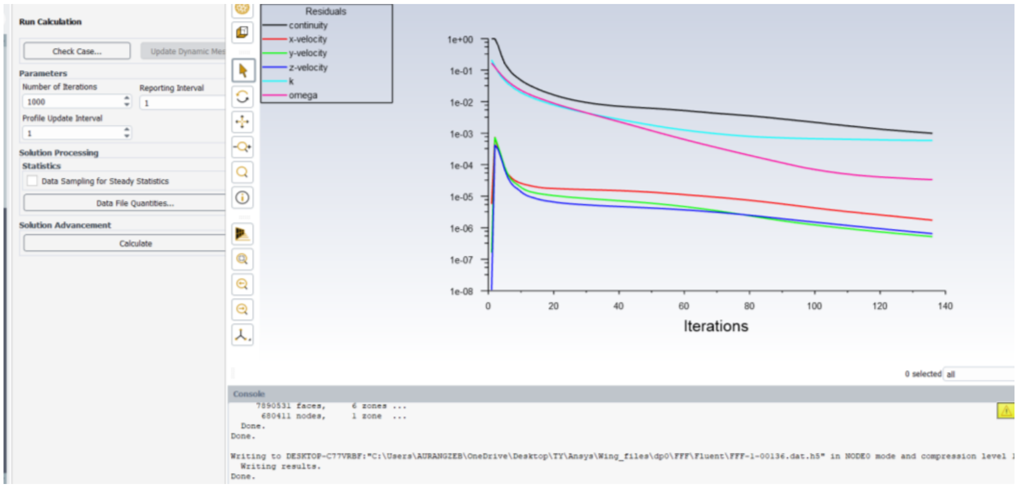


Figure 4-4: Velocity Contour

The diagram below illustrates different residuals and their convergence phenomenon. As it can be seen that all these resilduals are approximately being converged arounf 144 iterations.



Number of Iterations: 1000

Reporting Interval: 1

Profile Update Interval: 1

☐ Data Sampling for Steady Statistics

```
     7890531 faces,     6 zones ...
      680411 nodes,     1 zone  ...
  Done.
Done.

Writing to DESKTOP-C77VRBF:"C:\Users\AURANGZEB\OneDrive\Desktop\TY\Ansys\Wing_files\dp0\FFF\Fluent\FFF-1-00136.dat.h5" in NODE0 mode and compression level
  Writing results.
Done.
```

Figure 4-5: Convergence of Residuals

4.3.1 Theoretical Calculations at Zero Angle of Attack

The standard values of C_α and C_L for NACA 2412 at zero-degree angle of attack obtained from data sheet are as follows:

$$C_{\mathrm{L}} = 0.2183$$

$$C_{\mathrm{D}} = 0.018$$

These are the standard values which are set after doing series of experimentations.

$$L = C_L q_\infty S$$

The dynamic pressure on an airfoil is determined by the speed of the airflow and its density. It can be calculated using the following formula:

$$q_\infty = Dynamic\ Pressure$$

$$q_\infty = \frac{1}{2}\rho_\infty \mathrm{V}_\infty$$

The lift generated by an airfoil can be calculated using the lift equation, which is derived from Bernoulli's principle and the conservation of mass. The lift equation is as follows:

$$L = C_L \frac{1}{2}\rho_\infty \mathrm{V}_\infty^2 S$$

$$L = (0.2183)\left[\frac{1}{2}(1.225)(10)^2(1.3716 \times 0.17)\right]$$

$$L = 3.117\ \mathrm{N}$$

The drag on an airfoil can be calculated using the following formula:

$$D = C_{\alpha}\frac{1}{2}\rho_{\infty}V_{\infty}^{2}S$$

$$D = (0.018)\left[\frac{1}{2}(1.225)(10)^{2}(0.23317)\right]$$

$$D = 0.257\ N$$

$$\frac{L}{D} = 12.12$$

4.3.2 Conclusion

The analysis of the airfoil's lift-to-drag ratio (L/D) reveals consistent results between the computational fluid dynamics (CFD) analysis and theoretical calculations. The L/D ratio obtained from the CFD analysis is approximately 11.5, while the L/D ratio derived from theoretical calculations yields a value of approximately 12.12. The proximity of these two values indicates a high degree of agreement and suggests that both the analysis and design of the airfoil are sound.

The L/D ratio is a crucial parameter in assessing the overall efficiency of an airfoil. It represents the relationship between the lift generated by the airfoil and the drag it experiences. A higher L/D ratio indicates a more efficient airfoil design, as it signifies a greater lift generation relative to the drag encountered.

4.4 Six Degree Angle of Attack

During our analysis at a 6° angle of attack, we obtained compelling results in terms of lift and drag forces. The simulation revealed a lift force of 50.2 N, showcasing the ability of the airfoil to generate significant upward forces in the absence of any angle of attack. Simultaneously, the drag force was calculated to be approximately 2.5 N, indicating the resistance experienced by the airfoil in the direction opposite to the fluid flow. These outcomes provide valuable insights into the aerodynamic performance of the NACA 2412 airfoil under specific operating conditions and serve as a foundation for further optimization and design considerations in our project. The ratio of lift to drag comes out to be **20.8**.

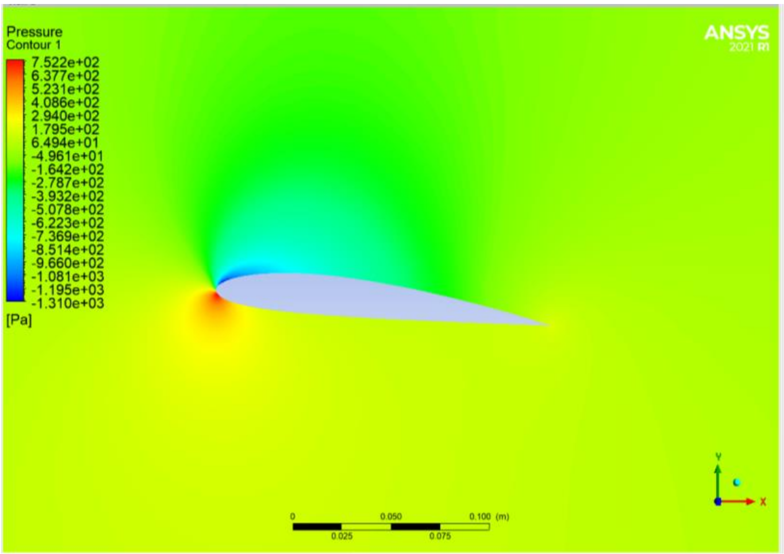


Figure 4-6: Pressure Contour

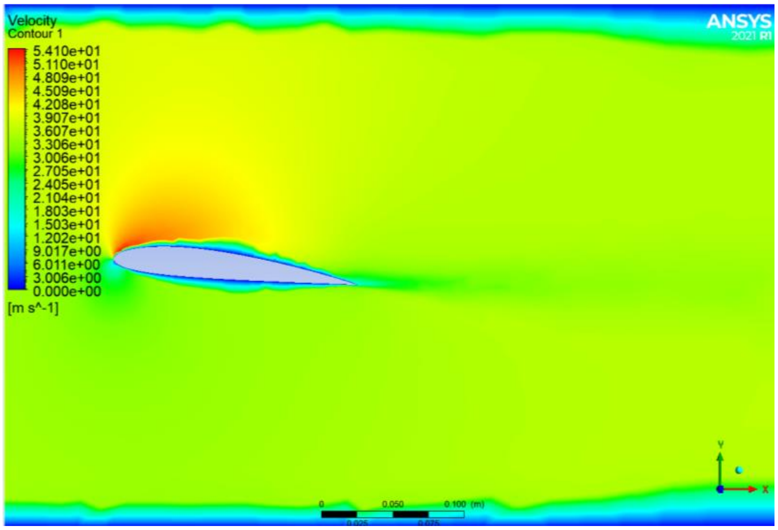


Figure 4-7: Velocity Contour

4.4.1 Theoretical Calculations at Six Angle of Attack

The standard values of C_{L} and C_{D} for NACA 2412 at 6°angle of attack obtained from data sheet are as follows:

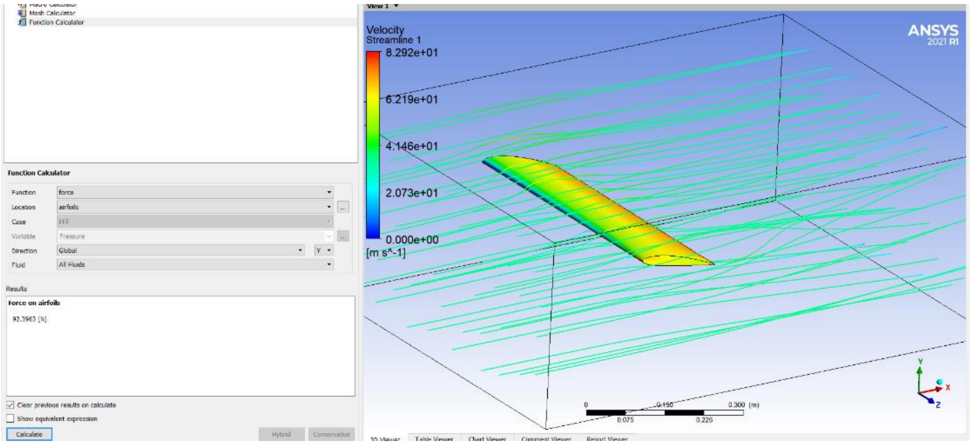
$$C_{\mathrm{L}} = 0.8100$$

$$C_{\mathrm{D}} = 0.048$$

Taking these two parameters and performing the same calculations as performed at zero angle of attack. The $\frac{\boldsymbol{L}}{\boldsymbol{D}}$ comes out to be about 16.87.

4.5 Thirteen Degree Angle of Attack

During our analysis at a 13° angle of attack, we obtained compelling results in terms of lift and drag forces. The simulation revealed a lift force of 92.3 N, showcasing the ability of the airfoil to generate significant upward forces in the absence of any angle of attack. Simultaneously, the drag force was calculated to be approximately 6.5 N, indicating the resistance experienced by the airfoil in the direction opposite to the fluid flow. These outcomes provide valuable insights into the aerodynamic performance of the NACA 2412 airfoil under specific operating conditions and serve as a foundation for further optimization and design considerations in our project.



Function Calculator

Function: force
Location: airfoils
Case: FFF
Variable: Pressure
Direction: Global Y
Fluid: All Fluids

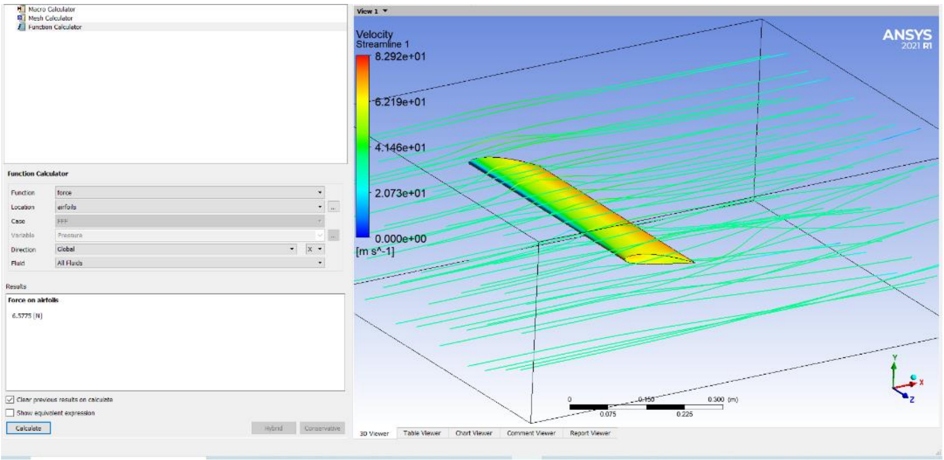
Results

Force on airfoils

92.3963 [N]

☑ Clear previous results on calculate
☐ Show equivalent expression

Figure 4-8: Lift



Function Calculator

Function: force
Location: airfoils
Case: FFF
Variable: Pressure
Direction: Global X
Fluid: All Fluids

Results

Force on airfoils

6.5775 [N]

☑ Clear previous results on calculate
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Figure 4-9: Drag

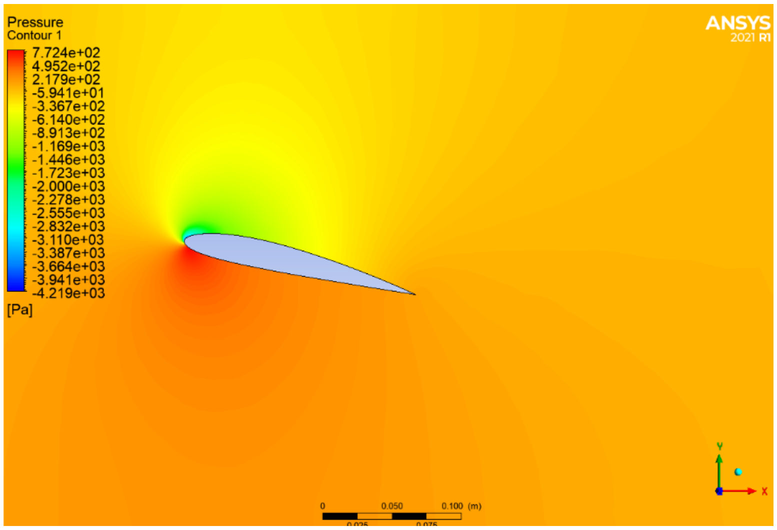

Figure 4-10: Pressure Contour

4.5.1 Theoretical Calculations at Thirteen Angle of Attack

The standard values of C_{L} and C_{D} for NACA 2412 at 13°angle of attack obtained from data sheet are as follows:

$$C_{\mathrm{L}} = 1.275$$

$$C_{\mathrm{D}} = 0.11665$$

Taking these two parameters and performing the same calculations as performed at zero angle of attack. The $\frac{\boldsymbol{L}}{\boldsymbol{D}}$ comes out to be about 10.9.

4.6 Flow Analysis

The analysis of the entire trans-wing RC plane is a critical and essential step in its design process. It involves considering a range of important parameters that significantly impact its performance. One such parameter is the size of the fluid domain, which is set at 30mm. This measurement is carefully determined to ensure accurate analysis and precise calculations.

Another vital aspect is the mesh size of the complete fuselage, which is established at 10mm. This mesh size plays a crucial role in capturing the intricate details and characteristics of the plane's structure. Additionally, a growth rate of 1.12 is applied, further refining the mesh to improve accuracy and reliability.

To accurately simulate the behavior of the trans-wing RC plane, the dimensions of the fluid domain are meticulously defined. The x-axis spans 72 inches, with the negative x-axis extending to 36 inches. The y-axis ranges from 25 inches to -25 inches, while the z-axis covers a distance of 50 inches to -50 inches.

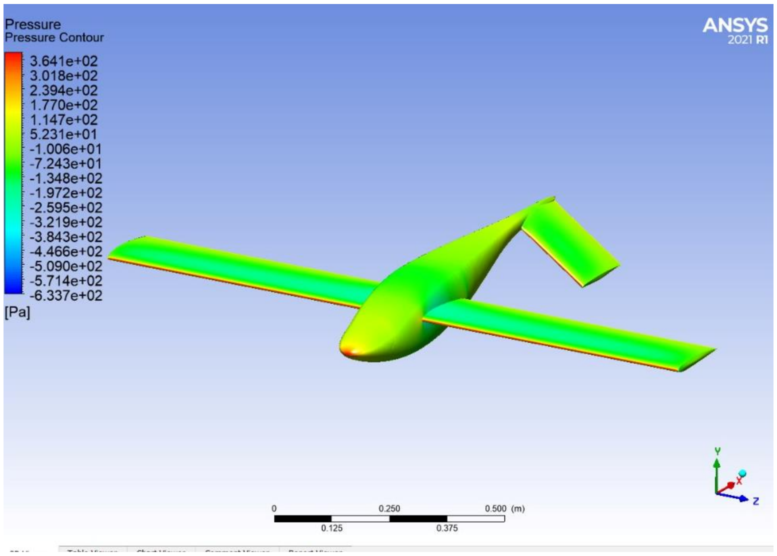

Figure 4-11 Pressure Contour

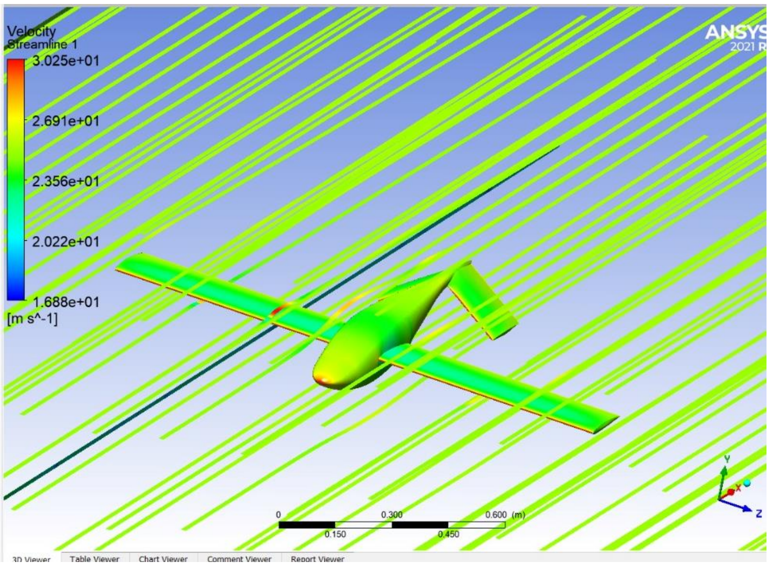

Figure 4-12 Velocity Streamline

4.7 Aerodynamic Center

The aerodynamic center is a specific point on an airfoil, wing, or other aerodynamic body where changes in the angle of attack have minimal effect on the pitching moment. In other words, it is the point along the chord line of the airfoil or wing where the moment generated by the aerodynamic forces remains relatively constant regardless of changes in the angle of attack.

From data of NACA 2412 the $C_L,\frac{c}{4}$ and $C_m,\frac{c}{4}$

At $\alpha = -6°$,

$$C_L,\frac{c}{4} = -0.39\ ,\ \ C_m,\frac{c}{4} = -0.045$$

At $\alpha = 4°$,

$$C_L,\frac{c}{4} = 0.65,\ \ C_m,\frac{c}{4} = -0.037$$

The aerodynamic center is given by:

$$X_{ac} = -\left(\frac{m}{a}\right) + \frac{1}{4}$$

$\frac{1}{4}$ is because moment is about quarter of the chord length.

m is the slope of moment co-efficient

α is the slope fo lift curve.

For lift curve slope, The formual is:

$$\alpha = \frac{C'_{L,\frac{C}{4}} - C_{L,\frac{C}{4}}}{\alpha' - \alpha}$$

$$\alpha = \frac{0.65 - (-0.39)}{4 - (-6)}$$

$$\alpha = 0.104 \text{ per degree}$$

For slope of moment co-efficient:

$$m = \frac{C'_{m,\frac{C}{4}} - C_{m,\frac{C}{4}}}{\alpha' - \alpha}$$

$$m = \frac{-0.037 - (-0.045)}{4 - (-6)}$$

$$m = 0.0008\, per\ degree$$

$$X_{ac} = -\frac{m}{a} + \frac{1}{4}$$

Substitute the values as follows:

$$X_{ac} = -\frac{0.0008}{0.104} + \frac{1}{4}$$

$$X_{ac} = 0.2423c$$

In our case the chord length is 17cm. It follows:

$$X_{ac} = 0.2423(17)$$

$$X_{ac} = 4.1191cm$$

So Aerodynamic Center is at 4.1191 cm from the leading edge.

4.8 Maximum Velocity and Stall Velocity

The maximum velocity and stall velocity of planes vary depending on the specific aircraft design and configuration. However, I can provide you with some general information.

The maximum velocity, also known as the top speed, refers to the highest achievable speed of an aircraft. This speed is determined by various factors such as engine power, aerodynamic design, and structural limitations. For commercial jetliners, the maximum velocities can range from approximately 0.8 to 0.9 times the speed of sound (Mach 0.8 to Mach 0.9). Supersonic fighter jets can achieve speeds well beyond the speed of sound.

The stall velocity is the minimum airspeed at which an aircraft can maintain level flight. It occurs when the angle of attack (the angle between the oncoming airflow and the aircraft's wings) exceeds a critical value, causing a loss of lift. The stall velocity is influenced by factors like aircraft weight, wing design, and configuration. Generally, smaller aircraft, such as light general aviation planes, have lower stall velocities compared to larger commercial aircraft.

$$C_{L,max} = 1.58$$

$$W = 22.23927\ N$$

$$\rho_\infty = 1.18kg/m^3$$

$$S = 0.241808\ m^2$$

$$V_{Stall} = \sqrt{\frac{2W}{\rho_\infty C_{L,max} S}}$$

$$V_{Stall} = 222.231.181.580.2418$$

$$V_{Stall} = 9.93\ m/s$$

Maximum Velocity

$$C_{D,min} = 0.009767$$

$$T = 1.2 \times 4 = 4.8 \times 9.81$$

$$T = 47.088\ N$$

Here, T represents the thrust.

$$V_{Max} = 247.088231.180.0097670.2418$$

$$V_{Max} = 183.83 m/s$$

4.9 Center of Pressure

The center of pressure (CoP) refers to the point on a body, such as an airfoil or wing, where the aerodynamic forces can be considered to act. It represents the average location of the pressure distribution across the surface of the body.

When an object, such as an airfoil, moves through a fluid medium like air, the flow creates varying pressures on its surface. These pressure forces contribute to the lift, drag, and pitching moments experienced by the object. The center of pressure is the point where these pressure forces can be combined into a single resultant force. The location of the center of pressure is influenced by several factors, including the shape, size, and angle of attack of the body, as well as the flow conditions. In general, the center of pressure tends to shift with changes in the angle of attack.

For NACA 2412

At α=4°

$$C_1 = 0.64$$

$$C_{m,\frac{c}{4}} = -0.036$$

$$\frac{X_{cp}}{c} = \frac{1}{4} - \frac{C_{m,\frac{c}{4}}}{C_1}$$

$$= \frac{1}{4} - \frac{(-0.036)}{0.64}$$

$$\frac{X_{cp}}{c} = 0.30625$$

$$X_{cp} = 0.30625c$$

For c=17 cm

$$X_{cp} = 0.30625(17) = 5.2cm$$

Center of Pressure is at 5.20625 cm from leading edge for 4 degree.

At 14°angle

$$\frac{X_{cp}}{c} = \frac{1}{4} - \left(\frac{-0.025}{1.56}\right)$$

For c=17 cm

$$X_{cp} = 4.522\ cm$$

Similarly, the same can be done at different angle of attacks and the variation in center of pressure can be analyzed.

4.10 Thrust Variation with Wing Rotation Angle

One of the important aspects investigated in this project was the variation of thrust with wing rotation angle for the trans-wing RC plane. This experiment aimed to analyze how changing the angle of wing rotation impacts the generated thrust during flight. Throughout the experiment, the angle of wing rotation was systematically adjusted, ranging from 0 degrees (representing the fully fixed-wing position) to 90 degrees (representing the fully rotary-wing position). The thrust produced by the propulsion system was measured concurrently with each wing rotation angle.

The findings revealed a noticeable relationship between the wing rotation angle and the resulting thrust. At lower wing rotation angles, closer to the fixed-wing position, the generated thrust was relatively lower. This can be attributed to the reduced lift production stemming from a decrease in the effective wing area. As the wing rotation angle increased, the thrust progressively increased as well, reaching its peak at a specific wing rotation angle. It is important to note that the peak thrust occurred at a particular wing rotation angle, beyond which further rotation caused a reduction in thrust. This decrease in thrust can be attributed to the compromised aerodynamic efficiency resulting from excessive drag and turbulence generated by the wing in the fully rotary-wing position.

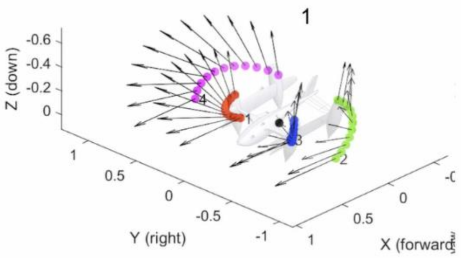

Figure 4-11 Variation of thrust

These observations provide valuable insights into optimizing the wing rotation angle to achieve the desired performance characteristics of the trans-wing RC plane. They emphasize the importance of finding the optimal balance between lift generation and drag reduction to maximize thrust and overall efficiency during different flight conditions.

The implications of these findings contribute to a better understanding of the aerodynamic behavior of trans-wing aircraft. They can serve as a foundation for further research and development in the design and control strategies of such aircraft, aiming to enhance their performance and operational capabilities.

4.10 Effect of Wing Transition on Yaw, Pitch, and Roll

The impact of wing transition on the yaw, pitch, and roll behavior of the trans-wing RC plane was thoroughly investigated. The experiment aimed to assess how the movement of the wings during transition influenced the stability and control of the aircraft across these three axes. During the transition process, as the wings of the aircraft moved from a fixed-wing position to a rotary-wing configuration, significant changes in the aircraft's behavior were observed in terms of yaw, pitch, and roll.

To visually demonstrate these effects, the following figure showcases the relationship between wing transition and the resulting changes in yaw, pitch, and roll behavior has been included. This visual aid enhances the comprehension of the observed effects.

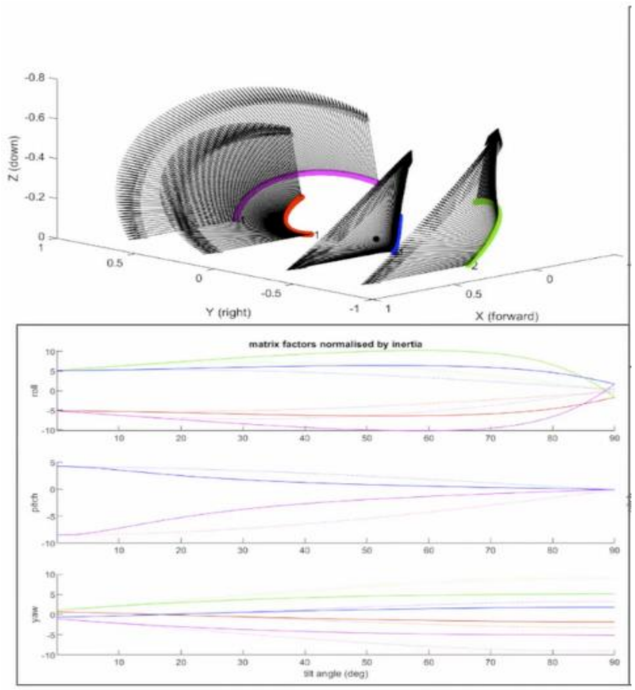

Figure 4-12 Variation of Yaw, Pitch and Roll

The transition of the wings had a substantial effect on the yaw stability of the trans-wing RC plane. The redistribution of lift and drag on the wings during the transition phase caused alterations in the aircraft's yawing tendencies. As the distribution of aerodynamic forces shifted, the aircraft's yaw response changed accordingly. This phenomenon was primarily influenced by modifications in the wing's effective area and the resulting variation in lift forces.

Additionally, the movement of the wings during transition exerted a considerable influence on the pitch behavior of the aircraft. Changes in the distribution of lift and the moment arm of the wings led to notable adjustments in the aircraft's pitching characteristics. The shift in the center of lift and alterations in the wing's aerodynamic properties played pivotal roles in determining the aircraft's pitch stability and control authority. Furthermore, the roll stability and control of the trans-wing RC plane were significantly affected by wing transition. The redistribution of lift and the resultant changes in aerodynamic forces during the wing transition process influenced the aircraft's roll behavior. The variation in lift distribution across the wings during transition led to modifications in the aircraft's rolling tendencies.

The experimental findings highlighted that wing transition played a critical role in determining the yaw, pitch, and roll behavior of the trans-wing RC plane. The alterations in lift distribution, drag, and the moment arm of the aircraft during wing transition directly impacted its stability and control characteristics across these three axes. Consequently, it became evident that careful design of the wing transition mechanisms, along with a thorough understanding of the resulting changes in aerodynamic forces, was crucial to achieve the desired stability and control behavior throughout different flight phases.

For further insight, it is important to note that the specific effects of wing transition on yaw, pitch, and roll behavior can vary depending on factors such as the design of the trans-wing RC plane, the wing configuration, the wing transition mechanism, and the flight conditions. Additionally, the interplay between these three axes is complex, as changes in one axis can influence the behavior of the others. Therefore, a comprehensive understanding of the aerodynamic principles and control systems involved is crucial to optimize the performance and stability of trans-wing aircraft. Further research and analysis in this field can contribute to advancements in the design and control strategies of such aircraft, leading to more efficient and maneuverable systems in the future.

CHAPTER 5 - MATERIAL AND COMPONENTS

5.1 Material and Components

The material selection and construction techniques used for the trans-wing RC plane were carefully considered to ensure the aircraft would be both lightweight and strong, while also being easy to work with. The materials and techniques used in the construction of the aircraft play a vital role in its performance, efficiency, and overall safety. In the construction of the trans wing RC plane, Balsa wood and carbon fiber rods were chosen as the primary building materials due to their combination of lightweight, strength, and durability. [13]

Here are some bullet points that explain the reasons why Balsa wood and carbon fiber rods were chosen:

- Balsa wood is lightweight, making it an ideal choice for an aircraft structure. It has a good strength to weight ratio, which means that the aircraft can be built strong and yet be lightweight. This is important for an aircraft as it will help to improve the overallperformance and efficiency of the aircraft.
- Balsa wood is easy to work with and it is versatile, making it suitable for a wide range of applications. It can be cut, sanded, and shaped to fit the specific needs of the aircraft. This allows for precise and accurate construction of the aircraft.
- Carbon Fiber rods are strong and stiff, which is important for the wing structure of the aircraft. It provides the required strength and stiffness to the wing without adding significant weight.
- Carbon Fiber rods are also lightweight and rigid, which helps to minimize the overall weight of the aircraft while providing a strong and stable structure.
- Aluminium material will be used for making the hinge at the point where wing will show transition, it is lightweight, strong and has good resistance against corrosion, whichmakes it suitable to be used in aircrafts.
- In summary, Balsa wood and Carbon Fiber rods were selected as the primary building materials. These materials were selected after careful analysis of their properties and how they will contribute to the overall performance and efficiency of the aircraft.

The component selection process for the trans wing RC plane was a thorough and systematic process that involved a careful analysis of aerodynamic and other important factors to ensure thatthe chosen components met the specific requirements of the aircraft. Components such as the motor, propeller, and battery were chosen based on their ability to provide optimal thrust and lift for the aircraft.

5.2 Motor

- Four Emax motors are being utilized as the primary power source for the trans wing RCplane.
- The Emax motors have been chosen after careful analysis of various parameters such aspower output, weight, and reliability.
- The motors have a thrust output of approximately 3.2 kg each, providing sufficient powerto lift and propel the aircraft through the air.
- The Emax motors are highly efficient, helping to prolong the flight time of the aircraft.
- They have high power efficiency, low internal resistance, and low heat dissipation, minimizing power loss.
- The motors are designed to be highly reliable, made of high-quality materials and haveundergone rigorous testing to ensure they can withstand the rigors of flight.
- The Emax motors ensure the aircraft will be able to operate safely and reliably duringflight tests.
- The motors were chosen due to their high thrust output, efficiency, and reliability.

5.3 Electronic Speed Controller (ESC)

The electronic speed controller (ESC) is a crucial component that regulates the power from the battery to the motor, allowing for precise control of the speed and thrust of the motor. In this trans wing RC plane, a 60A ESC is being used to ensure that it can handle the power requirements of the motors.

- High current capacity: The 60A ESC is capable of handling higher current loads, which is important for the power requirements of the motor used in the aircraft[14]. This ensures that the aircraft will be able to operate safely and reliably during flight tests.
- High thrust output: The 60A ESC can handle high power motors and provide high thrust output. This allows the aircraft to reach higher speeds and improve the stability of the aircraft.
- High efficiency, low internal resistance and low heat dissipation are other factors that make 60A ESC a good choice for this trans wing RC plane project

In summary, the 60A ESC was chosen for the trans wing RC plane due to its high current capacity, efficiency, and reliability. This ESC is able to handle the power requirements of the motor, minimizing power loss and ensuring optimal performance of the aircraft.

5.4 Power Source

In the construction of the trans wing RC plane, a 4S 5000mAh Li-Po battery is being utilized as the primary power source. This battery was chosen after careful analysis of various parameters such as energy density, voltage, capacity, weight and reliability.

The Li-Po battery is known for its high energy density, providing a large amount of power in a small and lightweight package. [15]The 4S (4 cell) voltage provides stable and consistent power to the aircraft, which ensures optimal performance during flight. The 5000mAh capacity provides a long flight time for the aircraft, which allows for extended flight duration. In summary, the 4S 5000mAh Li-Po battery was chosen for the trans wing RC plane due to its high energy density, voltage, capacity, weight and reliability. This battery can provide stable and consistent power to the aircraft, ensuring optimal performance during flight and extended flight time.

5.5 Radio Control System

In the construction of the trans wing RC plane, a Fly-Sky i6-X 10-channel transmitter and receiver is being utilized as the primary radio control system. This transmitter and receiver was chosen after careful analysis of various parameters such as channels, range, telemetry options, and ease of use.

The i6-X transmitter features a 10-channel design, providing a wide range of control options for the aircraft. This allows for precise and accurate control of the aircraft's various functions such as thrust, speed, and navigation. The Fly-Sky i6-X 10-channel transmitter and receiver was used in the trans wing RC plane project for its reliability, durability, wide range of control options, telemetry capabilities, and stable and reliable radio link between the transmitter and aircraft. [16]

5.6 Servo Motors

Servo motors are electromechanical devices widely used in various applications where precise control of angular or linear position, velocity, and acceleration is required. These compact and efficient motors are designed to provide accurate and reliable motion control in a wide range of industries, including robotics, automation, aerospace, and manufacturing [17]. The motors selected is of 25 Nm torque as it gives enough force to pull and push the connecting rods for transition purpose.

5.7 Connecting rods with ball joint

In the construction of the connecting rod, a thoughtful engineering approach was adopted to enhance its performance and durability. To achieve this, ball joints were strategically incorporated on both sides of the connecting rod. The utilization of ball joints allows for smooth and unrestricted movement, enabling efficient transmission of forces and accommodating angular variations during operation. These joints, with their low friction and high load-bearing capabilities, facilitate the optimal functioning.

Figure 5-1: Ball Joints with Connecting Rods

CHAPTER 6- FABRICATION

The intricate details of the fuselage and wings are carefully crafted and modeled using solid works, a powerful computer-aided design software. The internal profiles of the fuselage and wings are meticulously designed to ensure optimal structural integrity and aerodynamic efficiency. The result is a stunning 3D model of the internal structure of the fuselage and wingsof the trans-wing plane, which showcases the advanced engineering and precision that goes into the design and construction of this cutting-edge aircraft. The figure provided gives a clear visual representation of the intricate details and complex design of the fuselage and wings, highlighting the advanced technology and expertise that goes into the manufacturing of this plane. Therefore, a thorough design and testing process was undertaken to ensure the aircraft's overall structure and design was optimized for performance and stability during flight.

The design process included the following steps:

- Research and inspiration: Research were conducted on existing trans wing aircraft designs to gather inspiration and ideas for the project.
- Sketching and modelling: Sketches and models of the aircraft were created to visualizeand fine-tune the design.
- Final design: A final design was chosen, and all the required profiles were created.

6.1 Fuselage and Airframe Dimensions

In the design and construction of the trans wing RC plane, the dimensions of the fuselage and airframe were carefully considered to ensure optimal performance and efficiency of the aircraft. The length of the fuselage, from the head to the tail, was measured to be **36 inches**, while the diameter of the fuselage was **6 inches**. Additionally, the **wingspan** of the aircraft was measured to be **54 inches**.

These dimensions were chosen based on a variety of factors such as the aircraft's aerodynamic performance, weight, and structural integrity. The length of the fuselage and diameter were selected to provide the optimal balance between aerodynamic efficiency and structural stability, while the wingspan was chosen to provide the necessary lift and thrust for the aircraft.

In addition, the chosen dimensions also consider the aircraft's center of gravity and the location of the various components such as the motor and battery. This ensures that the aircraft is well balanced and stable during flight.

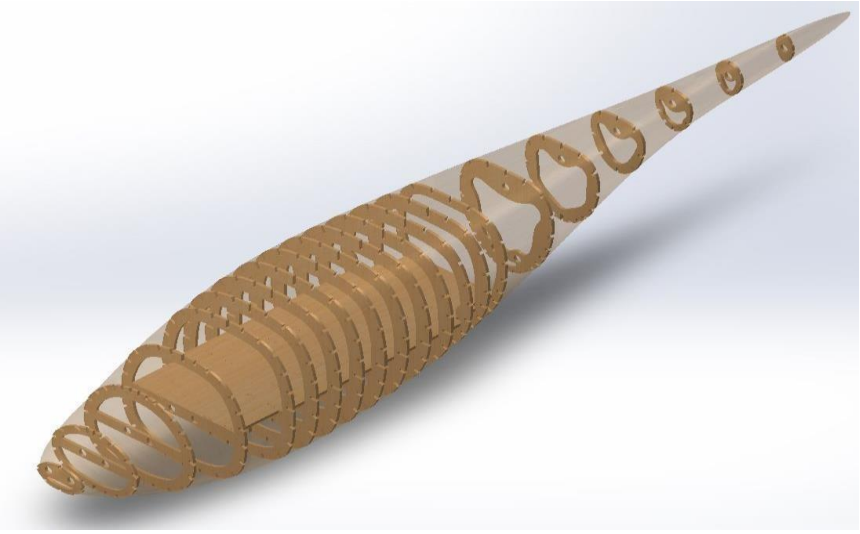

Figure 6-1: Air Frame

6.2 Profile Cutting and fabrication

In the profile cutting section, we converted the internal profiles made in solidworks model to a dxf file format. This is due to the reason that dxf file format is used in laser cutting. It is used in RD works software which operates laser cutting machine. The use of laser cutting technology ensured precise and accurate cuts which were important for the structural integrity and stability of the aircraft. By using this method, we were able to achieve precise and accurate cuts with minimal material waste.

The process of creating the dxf file from the solidworks model included the following steps:

- Exporting the internal profiles from the solidworks model to a dxf file format.
- Checking the dxf file for any errors or inconsistencies in the profiles.
- Making any necessary adjustments or corrections to the dxf file before proceeding withthe laser cutting process.

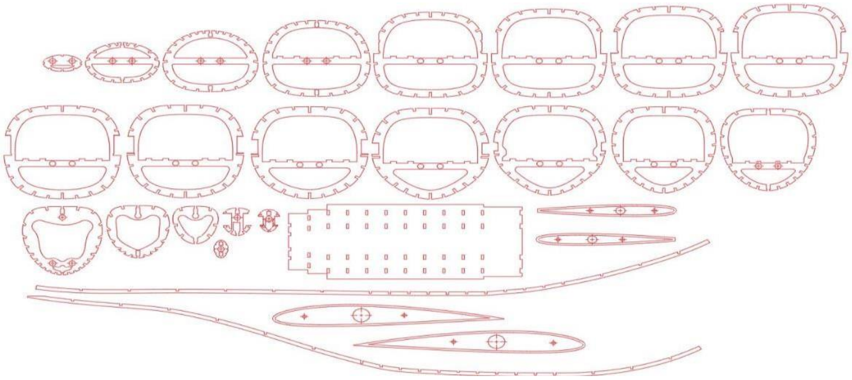

Figure 6-2: DXF file of internal Profiles

The balsa ply used in the construction of the trans wing RC plane was cut into individual profiles using laser cutting technology, ensuring precise and accurate cuts for the structural integrity and stability of the aircraft.

The final airframe of the aircraft was composed of 21 individual profiles. These profiles were then assembled to create the overall structure of the trans wing RC plane. The use of laser cutting allowed for precise and accurate cutting of the profiles and ensured that the final airframe was strong, lightweight, and accurate.

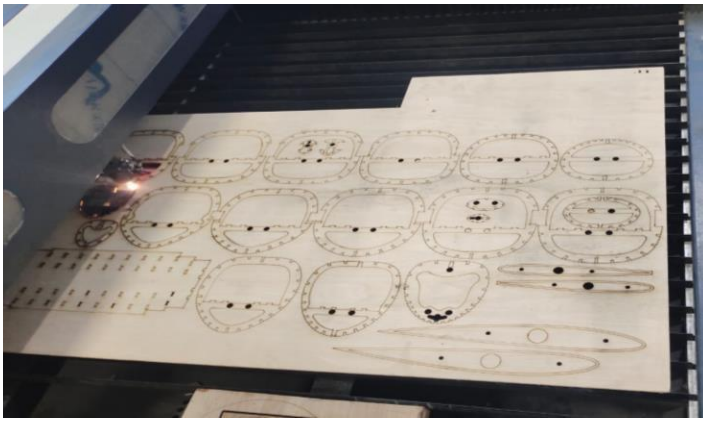

Figure 6-3: Laser Cutting

As part of the development process for our small-scale trans-wing RC plane, we have started to fabricate the fuselage portion and assemble the internal ribs or profiles. This stage of the project is crucial for ensuring the structural integrity of the aircraft.

First, we laser-cut the profiles for the wing and fuselage according to our detailed design drawings. This process allows us to achieve precise and accurate cuts that are essential for the proper fit and alignment of the various components.

Next, we began fabricating the fuselage by assembling the internal ribs or profiles. This process involves attaching the ribs to the fuselage using adhesive and other fastening methods. The ribs provide the necessary strength and support for the fuselage, and it is important to ensure that they are properly aligned and securely attached. We also paid close attention to the center of gravity (CG) during this stage of the project, as it is a critical factor in the stability and safety of the plane. We made sure that the CG is within the safe range throughout the entire transition phase by adjusting the position of the wings, fuselage, and other components.

As we move forward, we will continue to monitor the CG and make any necessary adjustments to ensure that the plane is stable and safe to fly. We will also be testing the plane with the wing mechanism installed to ensure that it performs as expected.

Overall, the fabrication and assembly of the internal ribs or profiles is an essential step in the development of our small-scale trans-wing RC plane, and we are confident that our attention to detail and careful execution will result in a functional and unique aircraft.

Figure 6-4: Fabrication of Fuselage

6.3 Hinge Fabrication

In order to create a hinge with precise specifications and desired mechanical properties, a strategic approach was adopted utilizing 3D printing technology. The hinge was fabricated using PLA-F (Polylactic Acid - Flexible) material, chosen for its favorable characteristics including flexibility and durability. The printing process employed a 35% infill, ensuring a balance between structural integrity and material efficiency.

The utilization of 3D printing and PLA-F material offered several advantages for the hinge's production. First, the 3D printing technique allowed for the precise realization of intricate design details, resulting in a high-quality hinge with accurate dimensions and smooth surfaces. The PLA-F material, known for its flexibility and strength, enabled the hinge to withstand repeated motion and operational stresses.

Figure 6-5: 3D Printed Hinge

6.4 Complete Assembled Model

Presented here is the meticulously assembled fabrication of our plane, showcasing the culmination of our dedicated efforts. The focal point of attention lies in the expertly attached hinge, serving as a pivotal component that enables seamless articulation and movement within the aircraft's structure. Its integration ensures smooth and controlled motions, facilitating efficient maneuverability and precise control during flight operations.

Additionally, the fuselage of the plane is adorned with a sleek and pristine white covering sheet, exuding an aesthetic appeal while also providing protection and structural integrity. The seamless integration of the covering sheet not only enhances the overall visual presentation of the plane but also contributes to its aerodynamic efficiency and resistance to external elements.

Accompanying the description, a series of meticulously captured photographs depict the complete model, showcasing its intricate design, impeccable assembly, and attention to detail. These visuals serve as a testament to the dedication, precision, and craftsmanship invested in the creation of this aircraft, allowing viewers to appreciate its beauty and functionality from multiple angles.

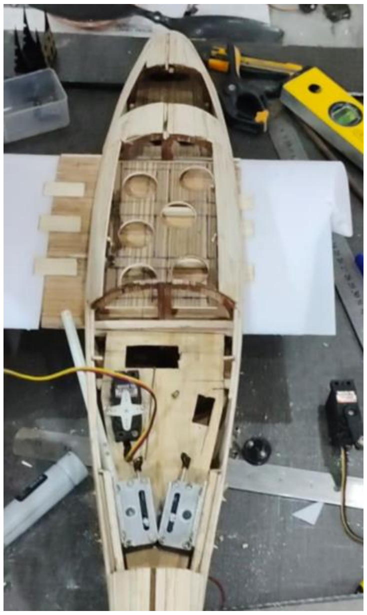

Figure 6-6: Fabricated Fuselage

Figure 6-7: Complete Fabricated plane (a)

Figure 6-8: Complete Fabricated Plane (b)

The wings of the aircraft are intricately connected to the hinge mechanism through the implementation of connecting rods, demonstrating a meticulous engineering approach. A notable feature of this arrangement is the utilization of ball joints on both sides of the connecting rods, facilitating unrestricted and smooth motion. These ball joints enable the wings to move freely, accommodating angular variations and ensuring optimal aerodynamic performance. By employing ball joints in this manner, the hinge mechanism allows for seamless articulation, enhancing the maneuverability and stability of the aircraft during flight. This meticulous design not only enables efficient transmission of forces but also emphasizes the importance of precision and reliability in achieving optimal wing functionality.

CHAPTER 7- FUTURE DEVELOPMENT PLAN

The project at hand involves the intricate and complex task of developing a transition mechanism for wings, and considerable progress has been made thus far. The ultimate objective of this final year project is to achieve a successful completion of the transition mechanism. However, it is important to note that this process is inherently iterative, requiring continuous refinement and testing.

One crucial aspect of this project is the flight testing phase, which is imperative to validate the effectiveness and functionality of the transition mechanism. Unfortunately, due to financial constraints, the project has not been able to allocate sufficient budgetary resources to conduct the necessary flight tests. This limitation has resulted in a delay in evaluating the performance and functionality of the mechanism in real-world flight conditions.

Nonetheless, looking towards the future, several potential avenues for improvement can be explored to ensure a successful outcome. One such area of focus could be the reinforcement of the hinge design for the wings. By enhancing the strength and robustness of the hinges, the mechanism would be better equipped to withstand the stresses and forces experienced during the transition process.

Moreover, optimizing the connecting rods within the mechanism presents another opportunity for enhancement. Through careful analysis and engineering, it may be possible to refine the design of these rods to improve their efficiency and reliability, ultimately contributing to a smoother and more seamless transition.

In addition to these specific areas of improvement, a comprehensive re-evaluation of the overall performance of the aircraft is warranted. This re-evaluation could encompass various aspects, such as aerodynamics, stability, and control systems, to ensure that the aircraft is optimized for successful transitions and overall flight performance.

7.1 Further Refinement of Trans-Wing Mechanism

It is worth noting that the restricted budgetary allocation for this project has resulted in the omission of the Pixhawk, an advanced autopilot system, from the current implementation. The primary focus thus far has been on accomplishing a successful transition mechanism, with the intention of incorporating the Pixhawk in future iterations. By integrating the Pixhawk and leveraging its capabilities alongside the propellers, the transition process can be further refined, offering a more comprehensive and sophisticated testing and evaluation platform.

The trans-wing mechanism is at the core of the versatility and adaptability of the trans-wing RC plane. To maximize its potential and ensure reliable operation, further refinement and improvements are necessary. This involves optimizing efficiency, enhancing reliability, and exploring advanced mechanisms for smoother wing movement.

7.1.1 Optimization of Efficiency

The efficiency of the trans-wing mechanism can be improved by reducing energy consumption during wing transition. This can be achieved through the exploration of advanced actuation mechanisms that minimize power requirements while maintaining precise control over the wing movement.

7.1.2 Enhancement of Reliability

Reliability is crucial for the safe and effective operation of the trans-wing RC plane. Further refinement of the trans-wing mechanism should focus on enhancing its reliability through the integration of robust mechanical components and redundant systems.

CONCLUSION

In conclusion, the design and fabrication of the trans-wing RC plane have demonstrated the potential for revolutionizing the aviation industry by combining the advantages of both fixed-wing and rotorcraft configurations. This project aimed to explore the capabilities and limitations of trans-wing planes and evaluate their performance. The testing and validation phase played a crucial role in assessing the performance of the trans-wing RC plane. By conducting thorough evaluations, the project team gained insights into the aircraft's flight characteristics, endurance, and range. The results obtained provided valuable data that can guide future improvements and modifications to enhance the plane's performance. The findings of this project highlight the immense potential of trans-wing planes in terms of their increased range, endurance, and adaptability. The ability to seamlessly transition between fixed-wing and rotorcraft configurations offers exciting opportunities for various applications, including education, defense, and emergency response.

Future work in this field should focus on further refining the trans-wing mechanism to optimize its efficiency and reliability. Additionally, conducting more extensive flight tests and evaluations in different conditions and scenarios would provide deeper insights into the capabilities and limitations of trans-wing RC planes. Overall, the design and fabrication of the trans-wing RC plane have paved the way for advancements in aviation technology. This project has shed light on the immense possibilities offered by trans-wing planes, and future research and development in this area hold promise for transforming the way we approach vertical lift and horizontal flight.

REFERENCES

[1] Cliquet, J., Houdeville, R., & Arnal, D. (2008). Application of laminar-turbulent transition criteria in Navier-Stokes computations. AIAA journal, 46(5), 1182-1190.

[2] Azariadis, P., & Aspragathos, N. (1997). Design of plane developments of doubly curved surfaces. Computer-Aided Design, 29(10), 675-685.

[3] Monroe, R. W. (1953). Improving the dynamic response of airplanes by means of electric equipment. Transactions of the American Institute of Electrical Engineers, Part II: Applications and Industry, 71(6), 441-449.

[4] Lang, J.D. and Francis, M.S. Unsteady aerodynamics and dynamic aircraft manoeuvrability, Paper 29, AGARD CP 386, November 1985.

[5] Bosch, S., Lacroix, S., & Caballero, F. (2006, October). Autonomous detection of safe landing areas for an UAV from monocular images. In 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 5522-5527).

[6] Adabo, G. J. (2014). Long range unmanned aircraft system for power line inspection of brazilian electrical system. Journal of Energy and Power Engineering, 8(2).

[7] Okulski, M., & Ławryńczuk, M. (2022). A Small UAV Optimized for Efficient Long-Range and VTOL Missions: An Experimental Tandem-Wing Quadplane Drone. Applied Sciences, 12(14), 7059.

[8] Abbott, I. H., Von Doenhoff, A. E., & Stivers Jr, L. (1945). Summary of airfoil data (No. NACA-TR-824).

[9] Abbott, I. H., & Von Doenhoff, A. E. (2012). Theory of wing sections: including a summary of airfoil data. Courier Corporation.

[10] Kussner, H. G. (1941). General airfoil theory (No. NACA-TM-979).

[11] Maksymiuk, C. M., & Watson, S. A. (1983). A computer program for estimating the aerodynamic characteristics of NACA 16-series airfoils (No. NASA-TM-85696).

[12] Kharulaman, L., Aabid, A., Mehaboobali, F. A. G., & Khan, S. A. (2019). Research onFlows for NACA 2412 Airfoil using computational fluid dynamics method. Int. J. Eng. Adv. Technol, 9(1), 5450-5456.

[13] Da Silva, A., & Kyriakides, S. (2007). Compressive response and failure of balsa wood. International Journal of Solids and Structures, 44(25-26), 8685-8717.

[14] Gong, A., MacNeill, R., & Verstraete, D. (2018). Performance testing and modeling of a brushless dc motor, electronic speed controller and propeller for a small uav application. In 2018 joint propulsion conference (p. 4584).

[15] Baronti, F., Fantechi, G., Leonardi, E., Roncella, R., & Saletti, R. (2011, September). Hierarchical platform for monitoring, managing and charge balancing of LiPo batteries. In 2011 IEEE Vehicle Power and Propulsion Conference (pp. 1-6). IEEE.

[16] Mach, V., Kovář, S., Valouch, J., Adámek, M., & Silva, R. M. S. (2017, November). Threshold levels of electromagnetic susceptibility for unarmed air vehicles. In 2017 Progress in Electromagnetics Research Symposium-Fall (PIERS-FALL) (pp. 2483-2488). IEEE.

[17] Firoozian, R. (2014). Servo motors and industrial control theory. Springer.