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ORIGINAL

E-VTOL Aircraft Assembling and Programming Using the Mission Planner Program

Montaje y programación de aeronaves E-VTOL mediante el programa Mission Planner

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ABSTRACT

This study presents the design and programming of a modern new class of radio-controlled electric vertical takeoff and landing (E-VTOL) aircraft using lightweight polylactic acid (LW-PLA). Utilizing the LW-PLA cork foam material is crucial to lowering the aircraft's total weight and improving its mechanical characteristics at the same time. The type of LW-PLA utilized in this study was specific, and its fabrication process was made possible by a Creality Cr 10s pro-3D printer. In this study, a lightweight polylactic acid was used to demonstrate the design of an electric vertical takeoff and landing (E-VTOL) aircraft (LW-PLA). It is essential to use the LW-PLA cork foam material to reduce the overall weight of the airplane and enhance its mechanical properties simultaneously. The particular kind of LW-PLA used in this model was manufactured using a Creality Cr 10s pro-3D printer. Solid Work version 2021 was utilized in the development of the mathematical model. Since radio-controlled aircraft capable of vertical takeoff and landing can carry out both tasks, the goal of this study is to find the best way to utilize the features that both airplanes and drones have in common. Consequently, the suggested model represents a sophisticated enhancement of the aerodynamic characteristics of the many types of radio control aircraft that are capable of performing vertical takeoffs and landings.

Keywords: E-VTOL; 3D-Printer; Solid Work; Wind Tunnel; Mission Planner.

RESUMEN

Este estudio presenta el diseño y la programación de una nueva clase moderna de aeronave eléctrica de despegue y aterrizaje vertical (E-VTOL) por radiocontrol que utiliza ácido poliláctico ligero (LW-PLA). La utilización del material de espuma de corcho LW-PLA es crucial para reducir el peso total de la aeronave y mejorar al mismo tiempo sus características mecánicas. El tipo de LW-PLA utilizado en este estudio era específico, y su proceso de fabricación fue posible gracias a una impresora Creality Cr 10s pro-3D. En este estudio, se utilizó un ácido poliláctico ligero para demostrar el diseño de un avión eléctrico de despegue y aterrizaje vertical (E-VTOL) (LW-PLA). Es esencial utilizar el material de espuma de corcho LW-PLA para reducir el peso total del avión y mejorar sus propiedades mecánicas simultáneamente. El tipo particular de LW-PLA utilizado en este modelo se fabricó utilizando una impresora Creality Cr 10s pro-3D. Para el desarrollo del modelo matemático se utilizó la versión 2021 de Solid Work. Dado que los aviones radiocontrolados capaces de despegar y aterrizar verticalmente pueden realizar ambas tareas, el objetivo de este estudio es encontrar la mejor manera de utilizar las características que tienen en común tanto los aviones como los drones. En consecuencia, el modelo sugerido representa una sofisticada mejora de las características aerodinámicas de los muchos tipos de aviones de radiocontrol capaces de realizar despegues y aterrizajes verticales.

Palabras clave: E-VTOL; 3D-Printer; Solid Work; Túnel de Viento; Mission Planner.

INTRODUCTION

The unmanned aerial vehicle (UAV), sometimes known as a drone, has been in existence for many decades and is widely used in military applications. In addition to its military applications, unmanned aerial vehicles (UAVs) are increasingly being used in a diverse range of sectors, including agriculture, rescue operations, and surveillance. Conceptually, an unmanned aerial vehicle (UAV) is described as an aircraft that operates without the presence of an onboard pilot.[1] Mini UAVs may be broken down into two distinct groups: those with fixed wings and those with multiple rotors. Miniature fixed-wing UAVs have more range than similarly sized multi-rotor systems that must have a runway or launcher for takeoff and landing. Multi-rotor UAVs, on the other hand, feature rotor systems with anything from three to four propellers, allowing them to perform VTOL, hover, and drop-off payloads from great heights. They are also more agile than fixed-wing UAVs because of their rapid transition from hover to cruise flight.[2] Several ways are available for the execution of vertical takeoff and landing (VTOL) operations, such as thrust vectoring, tilting wings or rotors, and tail-sitting, among others. The tail-sitting approach is considered the most basic technique for executing the VTOL maneuver since it eliminates the need for any supplementary actuators. The preference for a simplified mechanism in unmanned aerial vehicles (UAVs) arises from the advantages it offers, such as facilitating vertical takeoff and landing (VTOL) and decreasing operational costs, by effectively reducing the total mass of the aircraft. The tail-sitter is the fundamental kind of unmanned aerial vehicle (UAV) capable of vertical takeoff and landing (VTOL). This particular UAV is designed to ascend and descend by using its tail as a landing gear, thereafter transitioning into a horizontal orientation to facilitate forward flight. There is no need for additional actuators in this particular kind. In contrast to traditional designs, this aircraft can perform takeoff and landing operations in almost any unobstructed space, hence obviating the need for a specifically designated runway during the release and recovery phases.[3]

There have been several devoted and deployed studies dealing with different aspects of VTOL aircraft design and execution. Ahmed[4] this study included the use of a quadcopter equipped with four rotors and a video camera powered by a step motor. The quadcopter's flight and camera functions were controlled via the implementation of an Arduino board programmed in LabVIEW, alongside a mobile application. This project aims to decrease the expenses associated with constructing a quadcopter that can be controlled via a mobile device and is equipped with a video camera, achieving a cost reduction of almost tenfold. The stability and controllability of the video camera and quadcopter. The mathematical model was subjected to testing by SolidWorks and Ansys to ensure its validity.[5]

This research proposes a hybrid Unmanned Aerial Vehicle (UAV) with helicopter VTOL and hover flying capabilities and aircraft autonomy, payload capacity, and speed. Our aircraft design uses Tilt-Rotor mode transitions and Ducted-Fans for vertical flying. The aerodynamic design uses XFLR5 for preliminary design and ANSYS Fluent for fixed-wing verification. Experimental lift system testing was done using ducted fans for vertical flight. Next, we demonstrate aerodynamic design-based manufacturing. The designed avionics controls airplane control surfaces, vertical flight main lift systems, and motors and sensors. Finally, outside vertical flight testing proves the aircraft concept works.[6]

This paper deals with the conceptual design of fixed-wing Vertical Take-Off and Landing (VTOL) Unmanned Aerial Vehicle (UAV) of the mini category. The UAV is designed as per the mission requirement including wing, fuselage, empennage, and tilt-rotor mechanism. The UAV is then analyzed for its aerodynamic, performance, and stability analysis. Wing, fuselage, empennage, and tilt-rotor mechanisms are designed and modeled in OpenVSP and the whole UAV is analyzed in VSPAero. The UAV designed has a payload carrying capacity of 2kg – 4kg, a range of 90 km (with 2 kg payload), a stall speed of 11,8 m/s (without payload), 13,8 m/s (with 2 kg payload), and endurance of 1,52 hrs.[7]

This endeavor aims to create a visual inspection system for UAVs and verify its practicality on military aircraft. Using an autonomous system instead of trained humans enhances inspection safety and efficiency. Modified open-source coverage path planning (CPP) software enables the UAV to observe the complete aircraft's top surface. To verify computed pathways, images, flight data, and coverage estimates are collected via simulated and experimental flight testing. Simulation is used to forecast UAV performance during full-size aircraft inspections. Multirotor UAVs are a potential inspection platform for military aircraft, according to analysis.[8]

Since the advent of Fused Deposition Modeling (FDM) 3D Printing, filaments fabricated from a vast array of substances have been made accessible. For 3D printing, one company has been providing lightweight polylactic acid (LW-PLA). Color fab has the peculiar property of expanding at temperatures of about 230 °C. By estimating and working with the expansion, 3D-printed products' weights may be reduced.[9]

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Tail Setter VTOL RC Aircraft

A tail-sitter aircraft refers to a certain kind of aircraft that can vertically take off and land, undergo a mid-flight transition, and thereafter engage in cruising similar to that of a conventional aircraft. The majority of tail-sitter aircraft can alter the orientation of their fuselage over the course of a flight. Consequently, the pilot is required to assume a vertical posture during takeoff and thereafter adjust their attitude to a vertical position before the commencement of the cruising phase. These types of aircraft possess the attributes of both VTOL aircraft and fixed-wing aircraft capable of sustained horizontal flight, as opposed to rotary-wing flight.(10) A tail-sitter refers to an aircraft that is capable of vertical takeoff and landing. During horizontal flight, the main body of the aircraft tilts forward using either differential thrust or control surfaces. These types of tail-sitters are known as Control Surface Transitioning Tail-sitters (CSTT) and Differential Thrust Transitioning Tail-sitters (DTTT). In addition to their operability on compact platforms, VTOL aircraft have various benefits, including a higher level of energy autonomy when compared to multirotor aircraft.(11)

Figure 1. X-Vert VTOL Platform(12)

2D E-VTOL Design

Made by sketching using computer-aided design (CAD) software while the CAD design shows an E-VTOL aircraft.

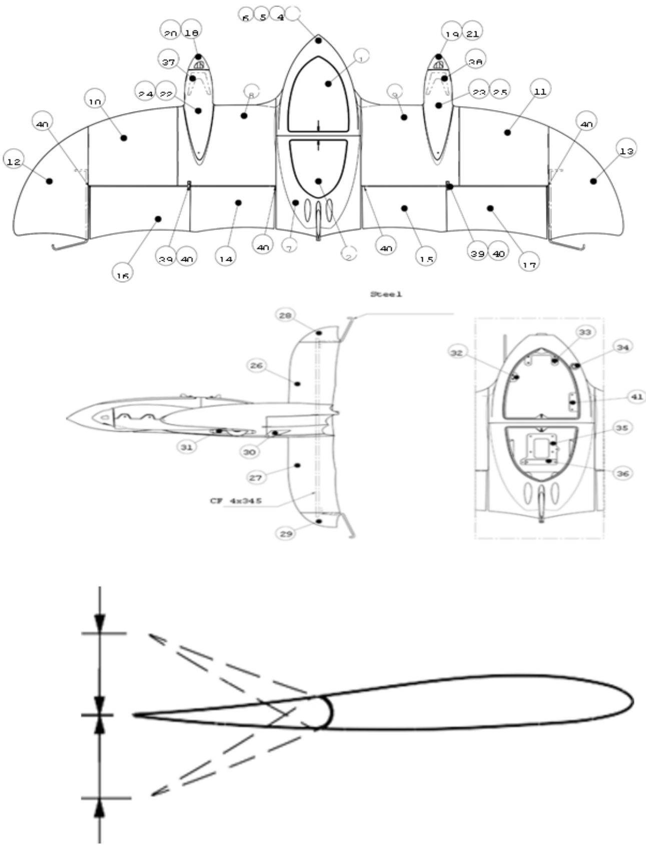

Figure 2. Model drawing using CAD software

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Design E-Vtol Using Solid Work

SolidWorks is a proprietary computer-aided design (CAD) program under Dassault Systems ownership. The software employs the notion of parametric design and produces three types of interrelated files, namely the component, the assembly, and the drawing. Consequently, any alteration made to any of these three files will be mirrored in the other two files.

Constructing the Model

The resolution of many technical challenges may be facilitated by the use of Solid Work Simulation, a well-recognized finite element method (FEM) software program. Additionally, it is used to juxtapose the observed behavior with the anticipated behavior, deriving inferences about the underlying nature of the matter at hand. The required steps for utilization are identical to those of any other Finite Element Method (FEM) software program.

- Select the Materials (Lightweight cork foam LW-PLA).
- Building the Model.

Modeling by Solid-Work

The construction of the model occurs after the suitable material has been selected, and the final configuration should closely mirror the chosen material in figure 3.

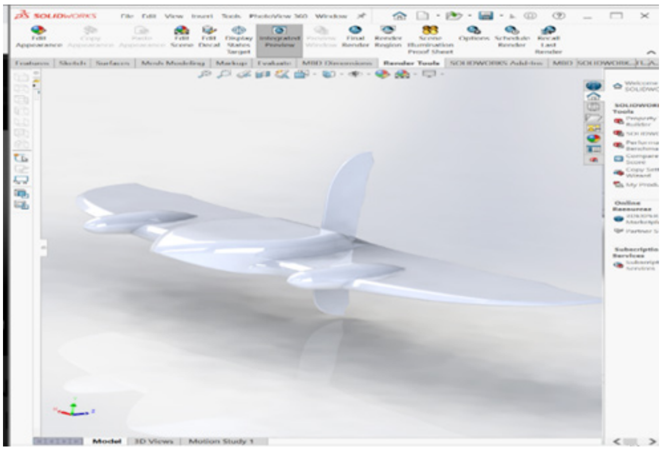

Figure 3. Representing the Solid-Work 3D Model

Wing Model

SolidWorks is a proprietary computer-aided design (CAD) program under Dassault Systems ownership. The software employs the notion of parametric design and produces three types of interrelated files, namely the component, the assembly, and the drawing. Consequently, any alteration made to any of these three files will be mirrored in the other two files.

Design Model

The wing section for NACA0015 was generated using SolidWorks 2021, with a chord line of 20 cm.

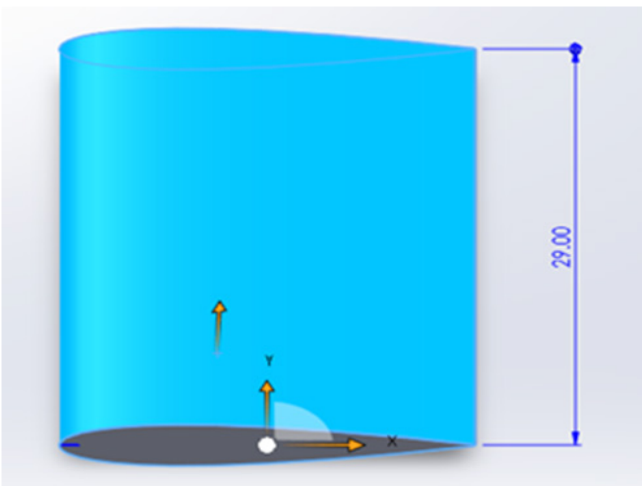

Figure 4. Geometry for NACA 0015

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Manufacturing Model

The wing was manufactured using a 3D printer and built of Lw-pla, as indicated.

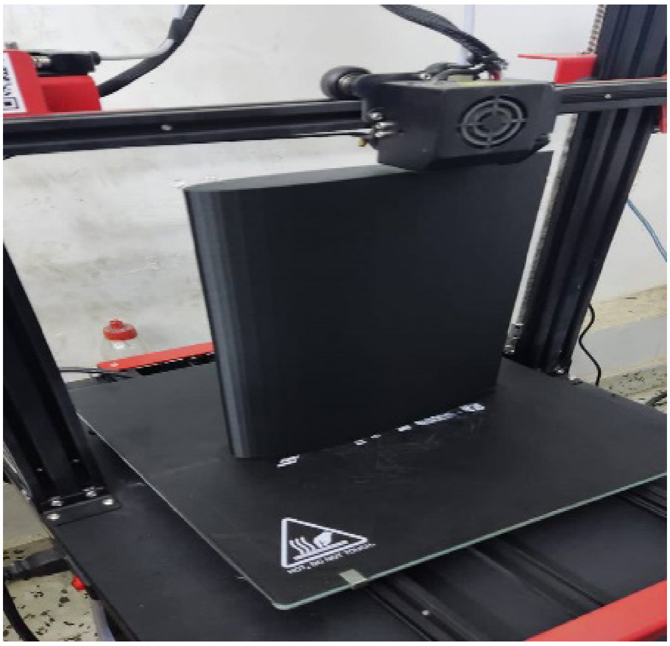

Figure 5. Airfoil's NACA 0015 at 3D printer

Wind Tunnel

The wind tunnel was utilized by the Directorate of Industrialization Research and Development at the Ministry of Science and Technology. The test section of the wind tunnel had dimensions of 30 cm x 30 cm x 60 cm. Within this test section, a sample was positioned, and its speed was measured using a Pitot Tube device. The device was set to a speed of 13,5 m/sec, and the readings were recorded using a calculator connected to the wind tunnel.

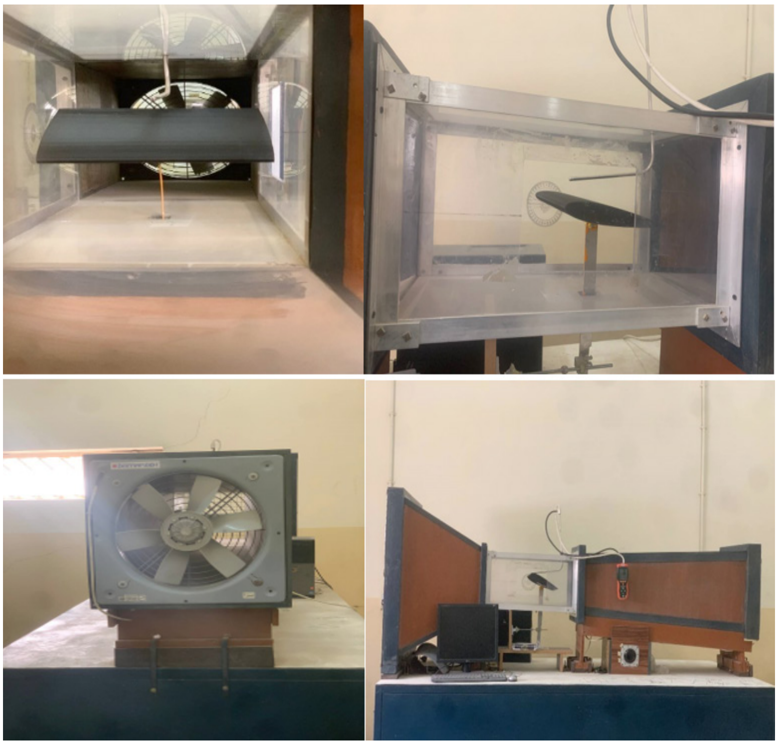

Figure 6. The wind tunnel equipment consists of four sides

Experimental Model

As sampling the Wing Model by 3D Printer

The Creality CR-10S Pro is well recognized as a prominent 3D printer, distinguished by its impressive technical specifications. The printer is capable of achieving precise and accurate printing of large objects due to its construction area of 300 x 300 x 400mm. The use of a robust metallic framework and the incorporation of a dual Z-axis configuration contribute to the production of prints characterized by superior quality. The CR-10S Pro is equipped with a filament sensor that is capable of detecting low quantities of filament. This feature serves to prevent errors during the printing process and minimize material waste, as seen in figure 7.

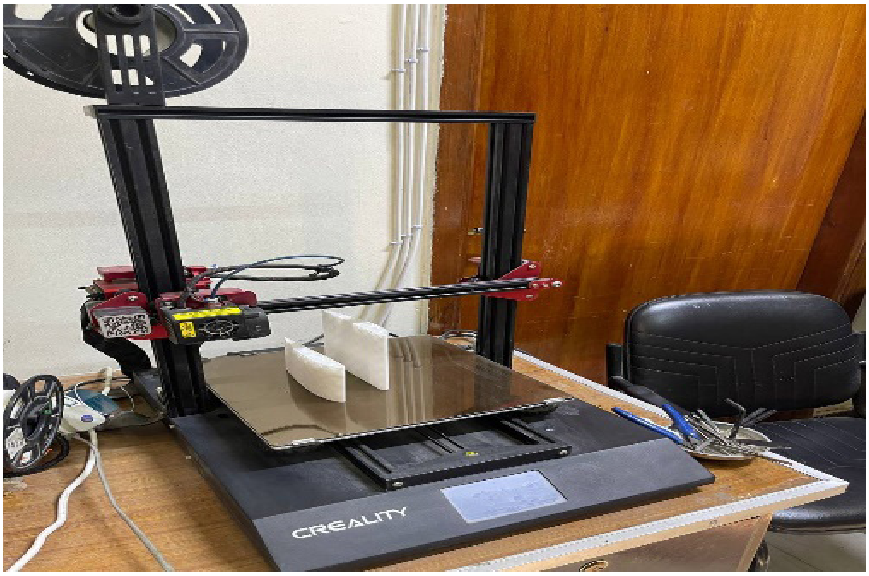

Figure 7. Creality Cr 10s Pro-3D Printer

Material Selection

The LW-PLA material was selected for the manufacturing of the E-Vtol because of its favorable mechanical and physical qualities, lightweight nature, cost-effectiveness, and high density.

Figure 8. The use of LW-PLA material in the manufacture of the E-VTOL aircraft frame

The frame of the E-VTOL

The structural framework of the Electric Vertical Take-Off and Landing (E-VTOL) aircraft is a critical component as it provides support and stability for the motors and other electrical systems. The selected material for this study was LW-PLA, which was chosen because of its lightweight nature and high-strength properties.

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Figure 9. The structure of (E-VTOL)

Brushless Motor

In this study, a pair of The A2212 Brushless Direct Current (BLDC) Motors is a commonly used out-runner type motor with three phases. The motor in question has a Motor kV value of 920 and is capable of generating a thrust of 500 grams.

Battery

The Lithium Polymer battery functions as the principal energy provider for the propulsion system and other electrical elements.

ESC (Electronic Speed Controller)

This study used two Qwin Out 2-4S 30A RC Brushless ESC Simonk Firmware Electronic Speed Controllers, which were specifically built to ensure compatibility with E-VTOL and multi-rotor systems. The ESC now under evaluation has higher motor speed control capabilities.

Receiver

The FS-iA6B receiver type has been used in our study. The 6-channel receiver exhibits a high level of compatibility with the FS-i6 radio transmitter, allowing efficient control of robotic systems within a maximum operating range of 500 meters.

Flight Controller

Pixhawk 2.4.8 PX4 32-Bit Flight Controller with Switch and Buzzer is the flight controller that we use. It is based on the always improving and developing Ardo-pilot mega. With the help of this incredible flight controller, the user can transform any fixed-wing, rotary-wing, or multirotor aircraft into a completely autonomous vehicle that is capable of carrying out a wide variety of activities, including planned GPS missions with waypoints when used in conjunction with the optional GPS Module.

Mission planner Software

After establishing a connection between the Pixhawk and our PC, we ran Mission Planner. Now you tell it which port the Pixhawk is connected to COM21(115200). We can choose to Install Firmware on the "Initial Setup" page. We chose plane 4.3.6 official. Now click on the Accel Calibration option. He demonstrates how to calibrate an accelerometer using Mission Planner from the most fundamental level. Calibration of the accelerometers in the autopilot is required so that any bias offsets or off-axis fluctuations may be corrected, as well as any bias offsets or off-axis variations. The compass calibration process configures all connected internal and external magnetometers. The mission planner will guide you to position the vehicle in several set orientations and rotate the vehicle about the specified axis. Click on the “Calibrate Radio” button on the bottom right. Manipulate the control sticks, knobs, and switches of the transmitter to their extreme positions. As a result, it indicates the lowest and highest values observed so far. Click on the “Full Parameter List” button. Q_ENABLE is selected and the value is changed from 0 to 1 to activate the vtol option. From the same menu, we click on the Q-FRAM-CLASS button and specify a value of 10. This will determine the type of FRAME we are working on. Click on the “Servo Output” button. We will have four options Throttles Left, Throttle Right, Elevon Left, Elevon Right. Since we have two engines, number 1 will be Lift and number 2 will be Right. Click on the “Flight Modes” button. We will do 3 options in this window. The first step is to activate the STABILIZE option. The flight will be vertical. Then we choose STABILIZE, the plane will be Fixed Wing. The third option will be QRTL, meaning the plane will return to the take-off location

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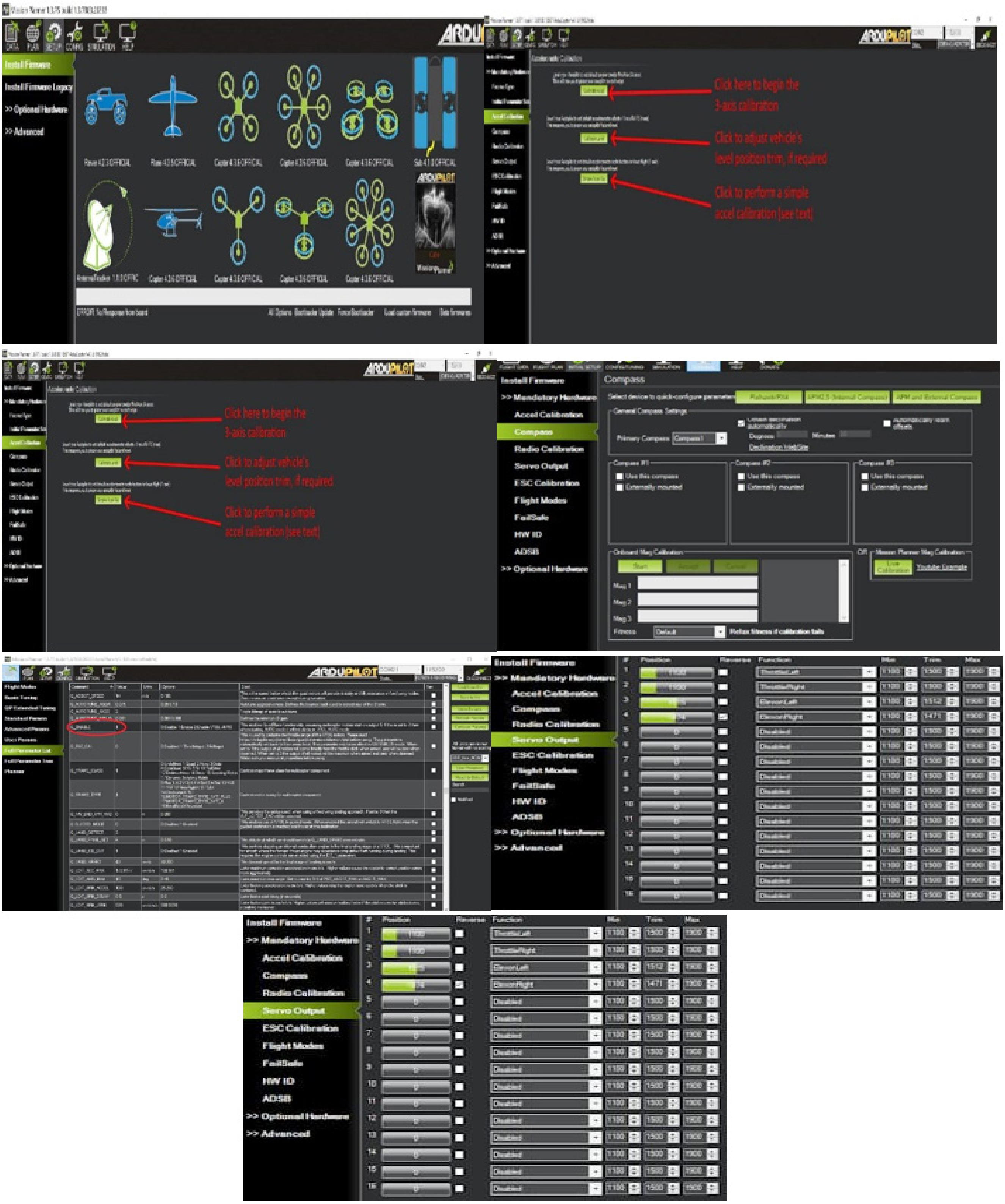

Figure 10. Mission Planer Steps

RESULTS AND DISCUSSION

The wing portion is positioned horizontally in the wind tunnel test chamber to send air flow through it at a zero angle of attack. It also has a spinning disc mounted on it to provide the wings with a changing angle of attack depending on the direction of the airflow for study and research, albeit the gadget does not include a wind tunnel. The magnitudes of lift and drag forces were determined by using a load cell, with data acquisition facilitated by computer-based means. The equation is used to get the coefficients of lift and drag, as shown.

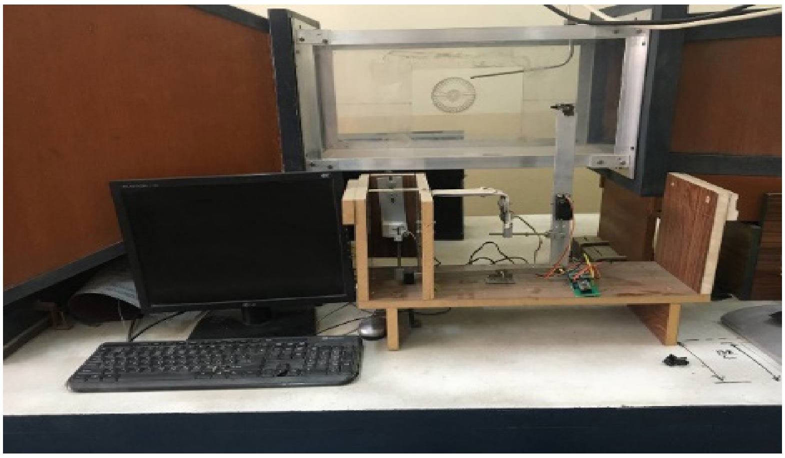

Figure 11. Using a Wind Tunnel to Measure the Lift and Drag Force

Table 1. The Values of The Force of Lift and Drag with Different Angles of Attack

Angle	Experimental 1		Experimental 2		Experimental 3	
	Drag force Gram	Lift force Gram	Drag force Gram	Lift force Gram	Drag force Gram	Lift force Gram
-11	86	320	92	330	80	313
-5	47	520	56	523	55	522
-3	43	723	50	720	40	720
0	39	925	45	920	33	934
3	35	1124	40	1132	30	1145
9	62	1240	69	1236	58	1233
15	200	1432	208	1458	195	1441

Table 2. The Values of Coefficients of Lift and Drag with Different Angles of Attack

Angle	Experimental 1		Experimental 2		Experimental 3	
	Cd	Cl	Cd	Cl	Cd	Cl
-11	86	320	92	330	80	313
-5	47	520	56	523	55	522
-3	43	723	50	720	40	720
0	39	925	45	920	33	934
3	35	1124	40	1132	30	1145
9	62	1240	69	1236	58	1233
15	200	1432	208	1458	195	1441

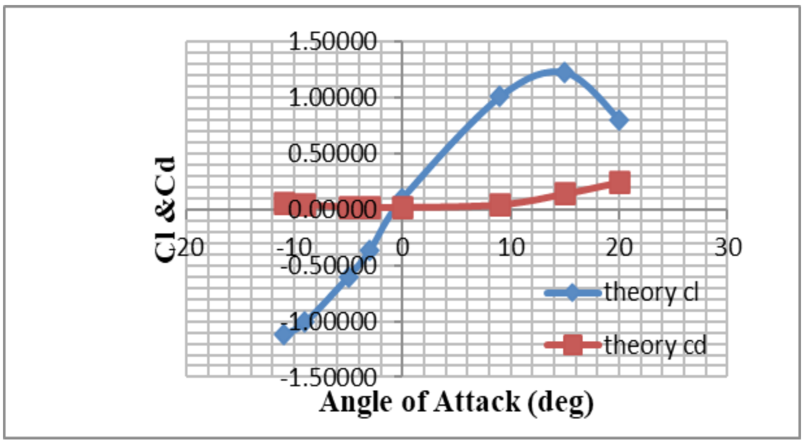

Figure 12. Coefficients of lift and drag with different angle of attack

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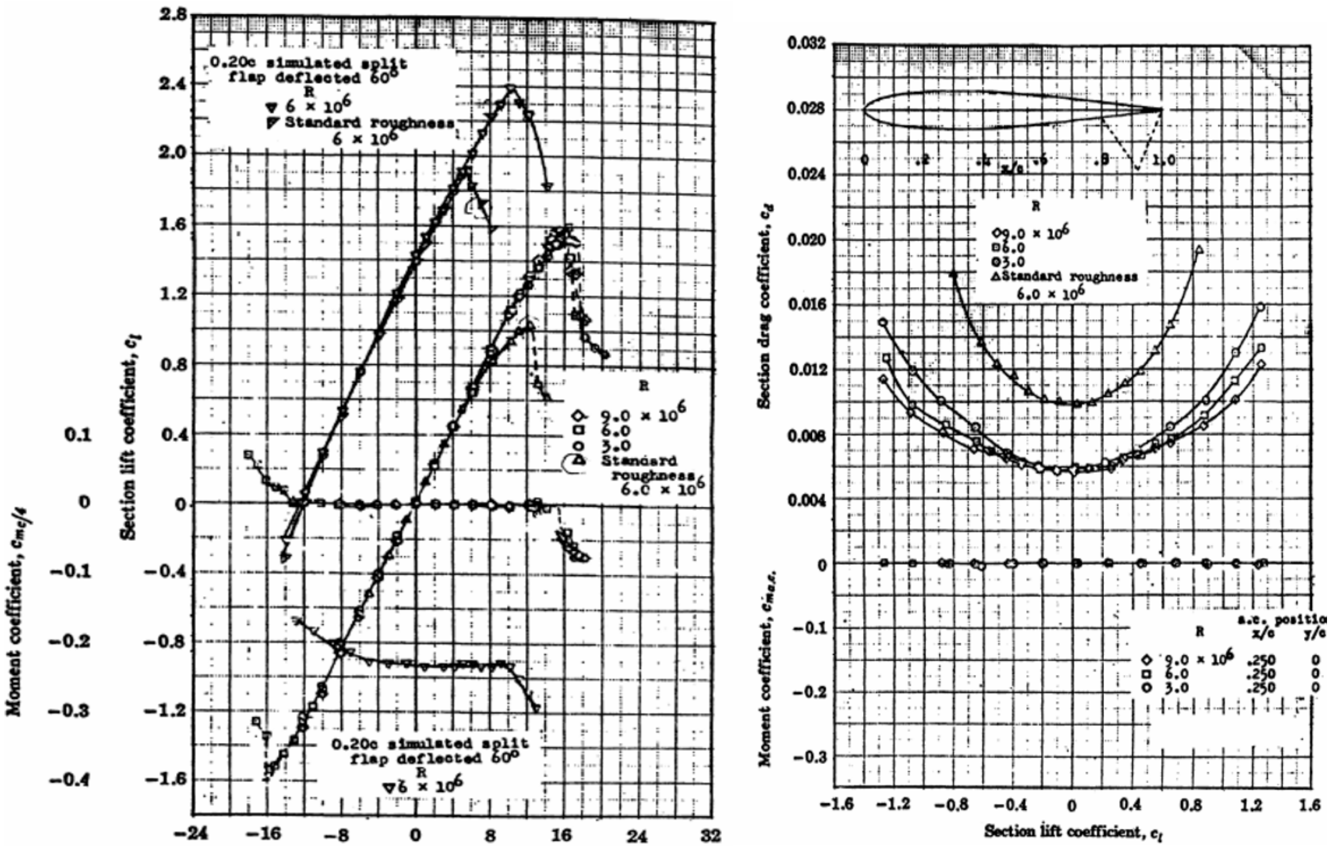

Figure 13. The Standard Values of the Relationship Between CL and CD with the Angle of Attack

CONCLUSIONS

In conclusion, the programming aspect of the E-VTOL aircraft project involves designing and implementing the necessary software and control systems to enable vertical takeoff, landing, and horizontal flight. While specific details about the programming languages and techniques used are not provided in the document, it can be inferred that the programming focuses on developing flight control algorithms, sensor integration, autonomous navigation, and mission planning capabilities. The programming plays a crucial role in ensuring the aircraft's autonomous operation and performance optimization. By utilizing the mission planner program, the aircraft can efficiently plan and execute missions, making it suitable for a wide range of applications such as reconnaissance, monitoring, rescue operations, agriculture, and more. Overall, the programming aspect of the project contributes to the advancement of technology in the aviation field, particularly in the development of electric vertical takeoff and landing aircraft. It opens up possibilities for enhanced performance, increased versatility, and expanded applications of unmanned aerial vehicles in various industries and sectors.

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All authors reviewed the results, approved the final version of the manuscript and agreed to publish it.

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Formal analysis: Zahraa Fadhil Ajaj, Ahmed Hameed Reja, Ahmed Adnan Shandookh.
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Writing - proofreading and editing: Zahraa Fadhil Ajaj, Ahmed Hameed Reja, Ahmed Adnan Shandookh.