DESIGN AND FABRICATION OF LOW COST FIXED WING UAV:A REVIEW

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Abstract
The Fixed Wing UAV project is aimed at developing an unmanned aerial vehicle (UAV) with a fixed-wing design that can be used for various applications, such as aerial mapping, surveillance, and monitoring. The project involves designing and building a prototype UAV that can be equipped with a range of sensors for data collection. The UAV will be powered by an electric motor and will have a wingspan of approximately 1 meter. The project team will also develop a flight controller for easy integration in the future. The project's ultimate goal is to produce a reliable and cost-effective UAV that can be used for a wide range of applications.
Keywords: – UAV, Wingspan, Flight controller, Servo, Fuselage length, Aspect ratio, communication module, Drag, Lift.

I. Introduction

A fixed-wing UAV is a type of drone that is designed to fly using wings that are fixed in place, as opposed to rotating blades like a helicopter. This design allows the drone to achieve greater speeds and cover larger distances than a rotary-wing drone [5,6]. Fixed-wing UAVs are used in a variety of applications, including aerial photography, surveying, mapping, and monitoring. They are often used in industries such as agriculture, construction, mining, and environmental monitoring, among others. One of the key advantages of fixed-wing UAVs is their long flight times. Because they are able to glide through the air, they require less power to stay aloft than rotary-wing drones, which need to constantly spin their blades to stay in the air. This allows fixed-wing UAVs to stay in the air for longer periods of time and cover larger areas in a single flight. Fixed-wing UAVs are also highly customizable. They can be equipped with a wide range of payloads, sensors, and other equipment to suit the needs of different applications.

Figure 1: Fixed Wing UAV

The fundamental concept behind unmanned vehicles is to digitally control machines and replace the need for human intelligence on board, thereby freeing up human capital for more efficient use. In comparison to manned aerial vehicles, UAVs offer two key advantages: they are cost-effective and mitigate the risk to pilot safety. They are frequently utilized in sectors such as agriculture, construction, and mining, where they can perform tasks such as crop monitoring, land surveying, and equipment inspection. As technology continues to advance, the potential for UAVs to be employed in new applications is vast.

1.1 Basic design parameters for fixed-wing UAV

Design parameters to consider when designing a fixed-wing UAV:

Wing Configuration: The wing configuration can be either a high-wing or low-wing design, depending on the mission requirements and aerodynamic considerations. A high-wing design provides better stability and payload capacity, while a low-wing design offers better speed and manoeuvrability.

Wingspan: The wingspan of the aircraft is a critical design parameter and should be determined based on the intended use, size, and weight of the aircraft. Generally, larger wingspans provide more lift and stability, while smaller wingspans offer greater manoeuvrability.

Wing Area: The wing area is another important parameter that should be proportional to the weight of the aircraft. It is a key factor in determining the lift and stability of the aircraft.

Airfoil Shape: The air foil shape of the wing is a critical design parameter that affects the lift and drag characteristics of the aircraft. The selection of an appropriate airfoil shape should be based on the intended use of the aircraft.

Fuselage Length: The length of the fuselage should be proportional to the wingspan and should be able to accommodate the necessary electronics and battery. It is an important factor in determining the overall weight and balance of the aircraft.

Weight Distribution: The weight distribution of the aircraft is a critical design parameter that must be balanced to ensure stable flight. The center of gravity should be located at an appropriate position relative to the wings.

Control Surfaces: The control surfaces, including the ailerons, elevator, and rudder, are critical design parameters that must be appropriately sized to provide the necessary control authority for the aircraft.

Power System: The power system, including the motor, propeller, and battery, is a key design parameter that should be selected based on the weight and intended use of the aircraft. The power system should be capable of providing sufficient thrust for takeoff and sustained flight.

1.2 Aerodynamic Design

Wing Loading: Wing loading is a parameter that represents the amount of weight supported by the wing area of an aircraft. It is calculated by dividing the total weight of the aircraft by the wing area. The formula for wing loading is as follows.

Wing Loading = Weight / Wing Area

Lift: The lift force (L) generated by the wings can be calculated using the lift equation.

$$L = 0.5 * \rho * A * Cl * V^2 \quad (1)$$

Drag: The drag force (D) opposing motion can be determined using the drag equation.

$$D = 0.5 * \rho * A * Cd * V^2 \quad (2)$$

Climb Rate: The UAV's climb rate (rate of ascent) can be calculated as the difference between thrust (T) and drag (D) forces.

Climb Rate = (T - D) / (mass * g)

Aspect Ratio: The aspect ratio is the ratio of the wing span to the chord length. It is an important factor that affects the lift and stability of the wing. The aspect ratio can be calculated using the following formula.

Aspect ratio = wing span² / wing area

Angle of Attack(α): The angle of attack is the angle between the chord line of the wing and the relative wind. The lift coefficient of a wing depends on the angle of attack, which can be calculated using the following formula.

$$\alpha = (L / (0.5 * \rho * V^2 * S)) - \alpha 0 \quad (3)$$

1.3 Electronic components

Flight Controller: This is the brain of the RC plane, responsible for stabilizing and controlling the aircraft. The CC3D is a powerful and affordable flight controller that is very popular to use mainly on mini quadcopters due to its small form factor. It has many advanced features that you can use if one adds a GPS module, even way point based flight. However, most users don't bother with this for mini quadcopters and just want the basic setup. [9,12,13]

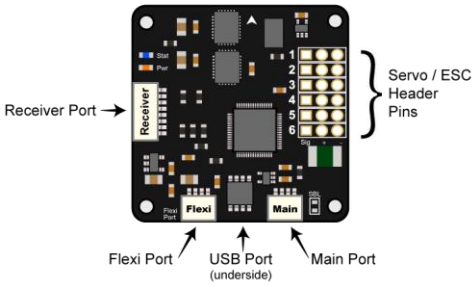

Figure 2 : CC3D Flight Controller

Battery and Power Distribution: UAVs require a reliable power source, typically in the form of batteries, along with a power distribution system to supply power to various components.In most of the cases a lithium polymer (li-po) batteries are used because of its low cost, increase capacity and good power delivery.

Figure 3 : Lipo Battery

ESC : regulate the power supplied to the motors, allowing precise control over their rotational speed. By adjusting the voltage and current delivered to the motors, the ESC can control the thrust generated by the propellers. ESCs are designed to work with specific voltage ranges, typically matching the voltage of the UAV's battery. It is important to choose an ESC that is compatible with the battery voltage you plan to use.[12,13]

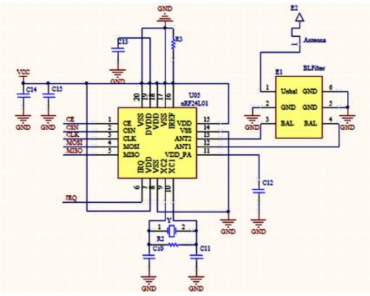

Figure 4: Schematic diagram of ESC

GPS Module: A GPS module enables the UAV to determine its position and navigate autonomously.

Motors and Propeller: Two types of motor are needed. BLDC and a servo.

A BLDC (Brushless DC) motor is a type of motor that operates using electronic commutation instead of brushes and a commutator. It offers several advantages over traditional brushed motors, including higher efficiency, longer lifespan, and better speed control.[12]

A servo motor is a type of rotary actuator that provides precise control over angular positioning. It consists of a motor, a gear system, and a feedback mechanism. The feedback mechanism provides information about the current position of the motor shaft. Servo motors are typically controlled using Pulse Width Modulation (PWM) signals. They can rotate from 0 to 180 degrees or more, depending on the model.[13]

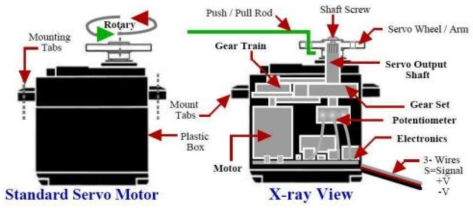

Figure 5 : Servo motor

A propeller is also needed to be mounted on the bldc motor so can it will produce the thrust to lift the uav.

Sensors: Various sensors such as gyroscopes, accelerometers, and altimeters are used for stability, navigation, and altitude control.[10]

The radio control system for a UAV (Unmanned Aerial Vehicle) is an essential component that enables remote control and communication between the UAV and the operator.

The transmitter is the handheld device held by the operator. It sends control signals to the UAV, including commands for throttle, pitch, roll, and yaw control. Transmitters often have multiple channels to control various functions of the UAV.

Figure 6 : Transmitter unit

The receiver is installed onboard the UAV and receives the control signals from the transmitter. It decodes these signals and relays them to the appropriate components, such as the flight controller or electronic speed controllers (ESCs).

Figure 7 : Receiver unit

Onboard Camera Systems: Cameras can be used for aerial photography, videography, or even for computer vision applications

Figure 8 : FPV camera

II. Literature

Naveed Ullah et al. [1] proposed that there should be modification in the process of designing Unmanned Aerial Vehicle. It was observed that the design of the aircraft depends upon its role. Enhancing one parameter, effects other parameters in various ways, due to which you should be cautious in your approach aiming your design goals.

S.N Logu et al. [2], said about replacing traditional flaps with aero elastic flexible wings which led to increase in performance parameters such as fuel efficiency and lift to drag ratio. The traditional flaps and aileron control surfaces are made flexible by covering the section with a rubber skin and making it an aeroelastic wing.

Krutik Patel et al. [3] detailed about the basic parameters need to design a radio-controlled plane and also reviews the research of other authors and observed that by optimizing the design parameters, the performance of the radio-controlled aircraft can be enhanced.

Omkar Bhosle et al. [4] motive of creating this paper is to encourage fellow students towards aerodynamics which is best achieved by creating an aerodynamic model. Their paper concentrate about three aspects of aircraft modelling they are designing, construction and electronics.

Siddhant Panigrahi et al. [5] talks about the various drawbacks of traditional multirotor and fixed-wing aircrafts and proposed a design of a hybrid fixed-wing bi-copter with thrust vectoring capabilities to overcome the range and endurance limitations of rotorcraft configuration. The novel design of the tilting motor pod allowed a smooth transition between the fixed-wing and VTOL phases, robust control over yaw, and pitch motions without any need for additional actuators during the VTOL hover phase.

MF saharudin [6] paper presents design of tilt rotor UAV and to perform the structural analysis the size of UAV’s wing section. By performing the structural analysis of the model, the results show that the design is safe for use.

Shreyas S Hedge et al. [7], proposed a systematic approach of building an radio-controlled plane from its designing phase to fabrication. In which they fundamentals of designing an aircraft overcome many problems during the fabrication phase.

B. Ravi Theja et al. [8] present work is carried out to obtain a concept design of the large UAV fuselage to yield the shape and material distribution for the determined loads and constraints within a design space. The UAV fuselage design is carried out to using Finite Element based approach and a fuselage design cycle has been developed. The advantages of the design cycle are minimum design time, less cost and reduced weight of the aircraft fuselage.

According to Alok Sinha et al. [9] This paper details the creation of a fixed-wing RC plane functioning as an Unmanned Aerial Vehicle (UAV).This design prioritizes stable flight and emergency applications, outperforming traditional models in flight tests. Additionally, the study investigates wing design's impact on aerodynamics, revealing decreased stability without winglets due to assumptions in ideal lift distribution. Overall, RC planes offer enjoyable, non-intrusive experiences, allowing users to practice mid-air control and promising satisfying flights for enthusiasts.

Shiva Sharma et al. [10] detailed about the systematic process of building a fixed-wing UAV for commercial surveillance, highlighting its advantages over typical multi-rotor systems. It begins with a broad global discussion on fixed-wing design, setting mission objectives and adopting a well-thought-out flight dynamics strategy. Progressing through the conceptual, preliminary and detailed design stages, the method involves rigorous calculations, modelling and structural analysis, culminating with the construction of the UAV.

Harish M et al. [11] centres on crafting a lightweight, electronically operated glider functioning at a 2.4 GHz frequency, placing significant emphasis on design and fabrication. It performs comparative analysis between experimental and computational tests, resulting in the successful flight of the operational prototype. Furthermore, it delves into exploring the practical applications of RC planes, highlighting the real-world implications of this aviation technology.

2.1 Flight Controller Unit

Aron Rasik Rai et al. [12] outlines the development and application of an Arduino Nano-based remote-controlled aircraft, leveraging an open-source microcontroller platform to attain precise control and maneuvering capabilities. The project's objective is to offer hobbyists and enthusiasts an affordable means of constructing and piloting their remote-controlled planes. Comprising two key elements—the ground control station (GCS) and the airborne unit—the system ensures comprehensive remote management.

Acoording to Mobasshir Mahbub [13] this design project introduces a controller unit using the nRF24L01 wireless transceiver module and Arduino Uno R3, offering the capacity to oversee multiple devices. Serving as a versatile radio controller, it extends its functionality to manage lights, servo motors, and DC motors, even extending to quadcopter operations. Comprised of both transmitter and receiver units employing nRF24L01 and Arduino Uno R3, this controller facilitates remote management of connected equipment. Notably, its adaptability extends to functioning as a quadcopter flight controller, easily adjustable through code modifications, highlighting its broad applicability. Its cost-effective construction empowers individuals to create and enhance this controller, enabling exploration of diverse applications and further research endeavors.

III. Conclusion

The design and fabrication of fixed-wing UAVs offer numerous advantages for various applications such as aerial mapping, surveillance, and monitoring. Fixed-wing UAVs have longer flight times, can cover larger areas in a single flight, and are highly customizable with a wide range of payloads and sensors. The article also discusses the basic design parameters and aerodynamic considerations for fixed-wing UAVs, including wing configuration, wingspan, wing area, airfoil shape, fuselage length, weight distribution, control surfaces, and power system. Additionally, it provides information on the Electronics system to be used in making the UAV.

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