"ADVANCED QUAD CAPTOR DRONE SYSTEM"

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Abstract - *Unmanned Aerial Vehicles (UAVs), such as drones and quadcopters, have revolutionized aviation, enabling humans to take to the skies in novel and significant ways. The military application of large-scale UAVs has expanded significantly, owing to their capacity to operate in hazardous environments while keeping human operators at a safe distance. This paper focuses specifically on the quadcopter as a form of small-scale UAV. As an unmanned aerial vehicle, it plays a pivotal role across diverse sectors, including surveillance, military operations, fire detection, traffic management, and various commercial and industrial applications. The primary objective of this research paper is to explore the design, construction, and testing procedures associated with quadcopters. In the proposed system, the structural design is predicated upon the estimated payload to be carried by the quadcopter, as well as the individual weight of each component; this approach facilitates the appropriate selection of the requisite electronic components. The selection of materials for the airframe is determined based on factors such as weight, the forces acting upon the structure, mechanical properties, and cost.*

Key Words: **UAV, Quadcopter, BLDC, ESC, Propellers, Motion, Thrust, Lift, Microcontroller,**

1. INTRODUCTION

A quadcopter is a heavier-than-air aircraft capable of Vertical Take-Off and Landing (VTOL). It is propelled by four rotors (rotating blades), which are mounted in a single plane and positioned parallel to the ground. Unlike conventional helicopters, quadcopters utilize 'fixed-pitch' blades in their rotors; their movement through the air is achieved by varying the relative speed of each individual propeller. The first quadcopter was the 'Michel 2,' invented by Etienne Omnichen in 1920. This aircraft successfully completed 1,000 flights and covered a recorded distance of 360 meters. Subsequently, in 1956, the 'Convert-a-Wings' model—a quadcopter designed by Dr. George E. Bothezat—emerged.[10] In the 21st century, incredible strides have been made in the field of quadcopters. Various universities, students, and researchers are working tirelessly to develop more capable controllers and modeling techniques, with the aim of enabling the detailed and accurate simulation of real-world quad rotors. Nikita Guliaev (2017) has articulated his views regarding the pricing of quadcopters. Today, even average consumers can purchase moderately sized quadcopters from major retail outlets or specialized stores. However, the price range for such aerial vehicles is often quite high. The primary objective of this article is to provide information regarding the design, construction, and practical demonstration of a quadcopter, thereby enabling students to easily and inexpensively build—right in the comfort of their own homes—a quadcopter capable of performing a wide variety of tasks across diverse fields. Anudeep and his colleagues (2014) presented a classification of quadcopters. They are categorized into two classes: 'micro' and 'mini' aerial vehicles; this classification is based entirely on their size and weight. Stafford Jesse (2014) explained the operational mechanism of quadcopters. This mechanism utilizes two pairs of identical 'fixed-pitch' propellers, wherein two propellers rotate in a clockwise (CW) direction and the remaining two rotate in a counter-clockwise (CCW) direction. To achieve control, the aircraft employs a method of independently varying the speed of each individual rotor. By adjusting the speed of each rotor, it becomes possible to achieve the following: generate a specific magnitude of desired total 'thrust' (forward-propelling force); precisely position the 'center of Thrust' in both horizontal and vertical directions; and generate the desired total 'torque' (rotational force). Quadcopters differ from traditional helicopters, as traditional helicopters utilize rotors capable of dynamically altering the pitch of their blades as they rotate around the rotor hub.

1.1 Quadcopter Design

The core component of a quadcopter is its frame, which features four arms. To accommodate a LiPo battery, four Brushless DC (BLDC) motors, a controller board, four propellers, a video camera, and various sensors, this frame must be both lightweight and robust. The speed of the BLDC motors is regulated by Electronic Speed Controllers (ESCs). To ensure greater stability—specifically by keeping the Center of Gravity (C.G.) low—the batteries are positioned within the lower half of the structure. The motors are mounted on opposing arms, equidistant from the center. The spacing between the motors is carefully calibrated to prevent any aerodynamic interference between the propeller blades. As illustrated in Figure 1, all these components are mounted onto the quadcopter's main frame or chassis. A detailed list of the quadcopter's components is provided in the Appendix section at the end of this article.

Nowadays, to enhance payload capacity while simultaneously reducing overall weight, the primary structural frame is typically constructed from carbon composite materials.

Fig. 1 Quadcopter Structure

1.2 Brushless DC Motors (BLDC Motor)

Brushless DC motors are utilized in quadcopters primarily because they possess an excellent thrust-to-weight ratio compared to brushed DC motors, and their commutators are integrated into the speed controller, whereas the commutators of brushed DC motors are located directly inside the motor itself. Being electronically commutated, they exhibit superior speed-versus-torque characteristics, offer high efficiency with noiseless operation, and provide a very wide speed range coupled with a longer lifespan. BLDC motors do not employ brushes for commutation. They are typically assigned two ratings: a Kv rating and a current rating. The Kv rating indicates the relationship between RPM and voltage; specifically, it denotes the speed (in RPM) at which the motor will rotate when supplied with 1 volt of voltage. The current rating specifies the maximum current that the motor can safely draw. By quantifying the electro-mechanical relationship, the torque constant Kt can be derived from the Kv rating, calculated as follows [7]:

1.3 Propellers

As shown in Figure 2, lifting thrust is generated to lift the quadcopter by rotating its propellers. Propellers come in a variety of shapes and materials. They are sized based on their diameter and pitch (Diameter x Pitch). Pitch is a measurement that determines the distance a propeller will travel in a single revolution. Selecting the appropriate propellers is crucial for generating the necessary thrust—whether for hovering stably in the air or for lifting off—without causing the motors to overheat. Each BLDC motor is fitted with a propeller. However, these four propellers are not, in fact, identical; the front and rear propellers are angled to the right, while the left and right propellers are angled to the left.

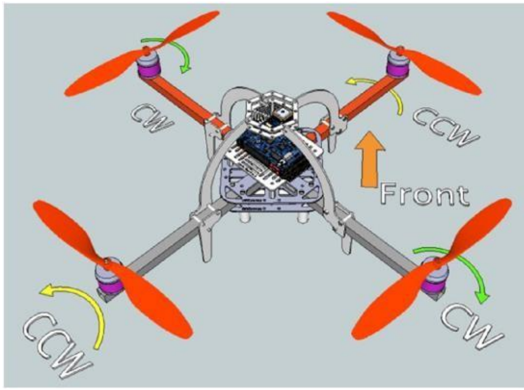

Fig. 2 Quadcopter Motor Rotation Directions [6]

1.4 Electronic Speed Controller (ESC)

Commands are issued in the form of PWM signals, which are received by each of the motor's ESCs, and the appropriate motor speed is output accordingly. The ESC converts the 2-phase battery current into 3-phase power and regulates the speed of the brushless motor based on signals received from the control board. The ESC used in radio-controlled vehicles performs two functions. The first function is to act as a Battery Elimination Circuit (BEC), enabling both the motors and the receiver to operate using a single battery. The second function is to receive signals from the receiver and flight controller and supply the appropriate current to the motors. Each ESC possesses a current rating, which indicates the maximum current it can supply to the motor without causing it to overheat. The ESC rating is higher than the motors;[10]

1.5 Battery

Lithium Polymer (LiPo) rechargeable batteries are used for quadcopters because they possess high specific energy and are lightweight. The battery supplies electrical energy to the quadcopter's motors and all electronic components. The capacity rating, expressed in milliampere-hours (mAh), indicates the amount of current the battery can deliver for one hour. The discharge rating—denoted by the letter "C"—indicates the rate at which the battery can be safely discharged. LiPo batteries are available in configurations ranging from a single cell (3.7V) to packs containing more than 10 cells (37V). The cells are typically connected in series, which increases the voltage while the ampere-hour capacity remains unchanged. The ESC rating exceeds the motor's amperage requirement; therefore, the maximum current drawn by the motor is Specified as it [11]

2. Design of Quad copter

The quadcopter system operates on the principle of generating lift through high-pressure air. There is no single definitive design for this type of UAV, as ongoing research into novel configurations renders traditional designs inherently fluid and subject to change. The objective behind every new design is to achieve greater stability and manoeuvrability. The stable flight of a UAV depends significantly on its structural design; furthermore, the inherent instability of the system introduces complexities into the design of its control mechanisms. The motion of a UAV is governed by the resultant forces and moments acting around its center of gravity. Precise mathematical relationships regarding the forces and torques acting around an object's center of gravity can be derived using the Newton-Euler model. For instance, if a UAV is required to hover at a specific altitude, the net moments acting around its center of gravity must be zero. The forces and moments exerted upon the center of gravity are contingent upon the specific structure and design of the vehicle. [1] The design of a quadcopter encompasses aspects of both mechanical engineering and computer engineering. A brief overview of the computer engineering aspects is presented in Figure 3. This implementation is executed in two distinct phases: software and hardware, respectively [3].

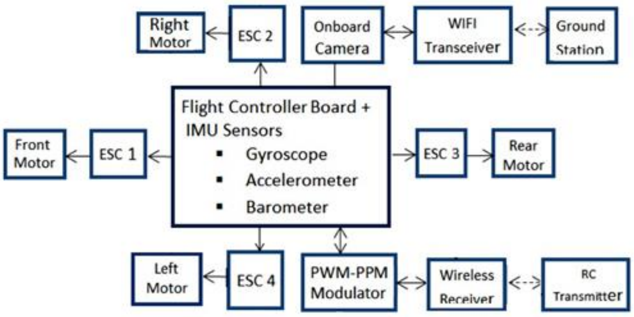

Fig.3 Block Diagram of Quadcopter

The design of a quadcopter is based on an embedded systems platform. It incorporates microcontrollers that govern the quadcopter's overall performance, including flight control systems and live video streaming. Following the microcontroller, Electronic Speed Controllers (ESCs) are utilized to regulate the propeller speeds in response to signals received from the onboard computer. Power is supplied to the quadcopter via a battery. These design elements collectively ensure that the quadcopter maintains stable flight, whether it is maneuvering or hovering motionless in the air. Typically, an X-type frame configuration is employed in quadcopters, as it is slender, lightweight, and sufficiently robust to withstand structural deformation caused by operational loads. Frames are generally characterized by either the motor-to-motor distance or the diameter of the circumscribing circle of the frame area. For mini aerial vehicles, the diameter of this circumscribing circle typically ranges from 0.25 meters to 1 meter. Depending on the specific application, a frame size corresponding to a 0.5-meter diameter is frequently selected for mini aerial vehicles [11]. When the frame is subjected to bending or torsional loads, the resulting deformation is directly correlated with the geometry of its cross-section. To minimize the quadcopter's overall weight, hollow frames with closed cross-sections are commonly utilized. In this context, the bending rigidity of a solid structure—as well as the torsional rigidity of a closed circular cross-section—are generally lower than those of a closed square cross-section. This design choice effectively contributes to a reduction in overall weight. Furthermore, the structural rigidity can be fine-tuned by adjusting the dimensions of the cross-sectional profile and the thickness of the frame walls.

3. CONCLUSIONS

This article presents the mechanical structure of a quadcopter and describes all its components; this design proves to be an excellent solution in scenarios where size and cost constitute the primary constraints on the quadcopter's construction. Compared to other structural configurations, the quadcopter design offers superior stability; furthermore—unlike other equivalent devices—it is capable of hovering steadily in close proximity to its target. In developed nations, projects of this nature play a pivotal role in diverse fields such as land surveying, the film industry, traffic management, and urban planning. The primary objective of this work is to conduct a comprehensive study—from an engineering perspective—of the quadcopter's overall design and manufacturing process, as well as to enhance its balance and stability systems. With an eye toward future potential, quadcopter technology is currently advancing at a tremendous pace. In recent times, companies such as Boeing, Airbus, DJI Innovations, Parrot, Walkera, Blade, and Heli-Max have been actively working on various projects, including the Bell Boeing Quad TiltRotor, AeroQuad, ArduCopter, Parrot AR.Drone, Nixie, Zano, and the Lily Camera drone.

REFERENCES

1. Faiyaz Ahmed, Y. Shivraj Narayan (2016), Design and Development of Quad copter for Surveillance International Journal of Engineering Research, Volume No.5 Issue: Special 2, pp: 312-318

2. Anudeep M., G. Diwakar, Ravi Katukam(2014), Design of A Quad Copter and Fabrication, International Journal of Innovations in Engineering and Technology, Volume No.4 Issue: 1, pp: 59-65.

3. BO Omijeh, VM Oden, KJ Joseph, JA Erameh (2016), Design and Construction of a Quadcopter with Payload for Pipeline Inspection and Surveillance, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Volume No.5 Issue: 6.

4. Harsha, Sree. (2014). Quadcopter, San Jose State University. San Jose, California. (Online:http://www.socialledge.com/sjsu/index.php?tit le=S14:_Quadcopter#Acknowledgement)

5. Saleh Abo Elmakarem (2014),Quadcopter Mechanics,UAVSociety.Egypt.(Online:http://uavsociety.blogspot.com/2014/06/quadcoptermechanics.html)

6. Jespersen, Thomas (2012), Quadcopters – How to getstarted,TKJElectronics.Denmark.(Online:http://blog.tkjelectronics.dk/2012/03/quadco pters-how-to-get-started/)

7. Nikita Guliaev (2017), The Design, Construction and Implementation of an Autonomous Outdoor Quadcopter using an RPi microcomputer and a MultiWii flight controller, Saimaa University of AppliedSciences,Finland.(Online:https://www.theseus.fi/bitstream/handle/10024/133527/Guliaev_Nikita.pdf?sequence=1&isAllowed

8. Øyvind Magnussen, Kjell Eivind Skjønhaug (2011), Modeling, Design and Experimental Study for a Quadcopter System Construction, University of Agder(Online:https://brage.bibsys.no/xmlui/handle/11250/ 136686)

9. Stafford, Jesse (2014), How a Quadcopter works | Clay Allen, University of Alaska, Fairbanks. Retrieved 2015, pp:01-20.

10. Mahen M.A, Anirudh S. Naik, Chethana H.D, Shashank

11. A.C (2014), Design and Development of Amphibious Quadcopter, International Journal of Mechanical And Production Engineering, Volume No.2 Issue 7, pp: 30-34.

12. Anand S. S, Mathiyazaghan R. (2016), Design and Fabrication of Voice Controlled Unmanned Aerial Vehicle, Journal of Aeronautics & Aerospace Engineering, Volume 5, and Issue 2.

13. https://quadcopterarena.com/the-history-of-drones- and-quadcopters/