DESIGN AND MANUFACTURE OF A HEXACOPTER DRONE

BY

IBIRONKE OLUWAPAMILERIN JOSHUA	**ENG 1905695**
IGBERASE BLESSED OSAGIE	**ENG 1905696**
IKADE AFAM VICTOR	**ENG 1905698**
IGHODALO ERONMOSELE JAHSWILL	**ENG 1905697**
HENRY DANIEL NOSAKHARE	**ENG 1805483**

DEPARTMENT OF MECHATRONICS ENGINEERING UNIVERSITY OF BENIN

FACULTY OF ENGINEERING

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PROJECT SUPERVISOR; PROF E.G SADJERE

A PROJECT WORK SUBMITTED TO THE

DEPARTMENT OF MECHATRONICS ENGINEERING,

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD

OF BACHELOR IN ENGINEERING (B.ENG) IN

MECHATRONICS ENGINEERING

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CERTIFICATION

We the undersigned, hereby certify that this work was carried out by **IGHODALO Eronmosele Jahswill, IBIRONKE Oluwapamilerin Joshua, IGBERASE Blessed Osagie, IKADE Afam Victor and HENRY Daniel Nosakhare** in the department of Mechatronics Engineering, Faculty of Engineering, University of Benin, Benin city. For the requirement of the award of the Bachelor of Engineering **(B.Eng)** Degree in Mechatronics Engineering.

Prof E.G Sadjere Date

Project Supervisor

Prof E.G Sadjere

Head of Department Date

Engr. Martins Osikhueme

Project Coordinator Date

DEDICATION

This work is dedicated to God Almighty who made everything possible through the gift of life.

ACKNOWLEDGEMENT

First and foremost, we want to acknowledge God Almighty who in his infinite mercies made everything possible. We also want to acknowledge the support of our parents and sponsors. Without their unwavering support financially, emotionally and in other aspects this work would not have been possible.

Finally, we recongnize the support of our Project Supervisor, Professor Sadjere who made the entire process easy, thus easing our minds. We say a very big thank you to you sir.

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ABSTRACT

This project focuses on the design and manufacture of an hexacopter drone capable of performing a wide range of applications, from aerial photography and surveillance to cargo delivery and environmental monitoring. The objective of this project is to develop a functional and reliable hexacopter that meets the necessary performance requirements, such as stability, payload capacity, flight time, and control accuracy.

Design of this drone comprised of the assembling of different parts together. Such parts include: propellers, motors, hexacopter frame, lithium polymer battery and so on.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The term UAV is an acronym for Unmanned Aerial Vehicle. Its scope covers all vehicles with no personnel on board capable of controlling the aircraft. (Eisenbeiss et al 2004). This term is used commonly in computer science and the artificial intelligence world but terms like Remotely Piloted Vehicle, (RPV), Remotely Operated Aircraft (ROA), model helicopters are also used.

The rise of unmanned vehicles and drones has been one of the major technological advancement in recent years. Their growth can be attributed to advancements in several fields, including aviation, robotics, communications, and data analysis. The development of UAV systems has been strongly motivated by military applications. As wars were waged across the world, it was discovered that it is less risky to deploy machines in place of humans in very risky places with high probability of large casualty rate. War hungry leaders looked for ways to solve and thus the idea of the unmanned aerial vehicle for conceived. After world war two, some nations began looking for ways to deploy UAV's for applications such as surveillance, reconnaissance and penetration of hostile terrain (without deploying humans). (Eck, 2001). In the 1910's, the concept of radio controlled aircraft emerged with some of the experimental UAVs used for training anti-aircraft gunners. These early models were primitive and not yet fully automated. As technology advanced, UAVs started to gain more sophistication, using more advanced radio control systems. The technology for remotely piloted aircraft improved as radio communications and flight control systems evolved. In the later years of the war, UAV technology began to show potential for offensive uses, such as reconnaissance and even potential weapons delivery. However, most UAVs remained limited to training and testing during this period. The Cold War saw a dramatic increase in the development and deployment of UAVs for military and intelligence purposes. The US military played a major role as the development and advancement of the drone technology continued. The U.S. Air Force developed more sophisticated reconnaissance drones for aerial surveillance in the 1950s. These drones were often used to collect intelligence over hostile territories, without putting human pilots at risk. One of the most notable UAVs from this era was the Ryan Model 147, developed in the 1960s, which was used by the U.S. military for reconnaissance missions during the Vietnam War. It marked a turning point, demonstrating the feasibility of UAVs as effective reconnaissance platforms. The Model 147 was a precursor to the Puma UAVs used by modern forces. The first generation of UAVs with weapons capabilities began emerging. The MQ-1 Predator, developed in the 1990s, was capable of carrying precision-guided munitions and conducting both surveillance and strike missions. The Predator, developed by General Atomics, was an early. As the years progressed, there was further improvements in UAV technology. The primary use remained military, but drones began to incorporate more sophisticated surveillance equipment, including cameras and sensors, for real-time intelligence gathering.

The first generation of UAVs with weapons capabilities began emerging. The MQ-1 Predator, developed in the 1990s, was capable of carrying precision-guided munitions and conducting both surveillance and strike missions. The Predator, developed by General Atomics, was an early example of the UAV's transformation into a true combat asset, able to perform targeted strikes without risking human pilots. While UAVs were still primarily military tools, the commercial sector began to explore their potential for non-defense purposes. UAVs began to be used for scientific research, disaster relief, environmental monitoring, and media production. A major driver was the miniaturization of UAV components, which made them more affordable and accessible.

Later on, UAVs became popular in not just the military market but also the consumer market. This was largely driven by the development of drones that were easy to fly, affordable, and capable of capturing high-quality images and videos. Companies like DJI led the way, with consumer drones like the Phantom series revolutionizing aerial photography, filmmaking, and recreation. As a result, UAVs began to be used in industries ranging from agriculture (for crop monitoring and spraying) to real estate (for aerial property photos) and logistics (such as drone delivery trials). The ability of UAVs to quickly cover large areas of land, deliver goods, and gather data has expanded their application exponentially. As drone technology became more widespread, countries around the world began introducing regulations to ensure safety and privacy. This includes restrictions on where and when drones can be flown, as well as the introduction of pilot certification programs. Notably, the FAA in the U.S. began issuing Part 107 regulations for commercial drone use in 2016.

There are different types of drones (UAVS) and they are classified according to size, purpose, flight range and endurance, configuration and design, Types of drones under the classification of size include nano drones micro drones. Nano drones are small and typically weighs less than 250 grams. They are ultra-small drones, often used for indoor flying or as demonstration tools. They are generally not equipped with powerful cameras or sensors and are used for basic functions like flying practice. Micro Drones are slightly larger than nano drones, and they weigh between 250-500 grams. These drones are also used for recreational purposes and light tasks like aerial photography in controlled environments. Examples include small personal drones used for video recording or hobby flying.

Types of drones under the classification of purpose and use include, combat drones, surveillance drones, agricultural drones etc. Types of drones under the classification of flight range and endurance include; short range drones (under 10km), medium range drones (10-50km). large range drones (beyond 50km). Drones can also be classified based on the number of propellers they have. This project will be focused on this classification. This classification of drones typically refers to the number of rotors used to provide lift and control during flight. Below is an overview of the different types of drones categorized by their propeller count:

1. Tricopter (Three Propellers):

i) Propellers: 3

ii) Design: Tricopters have three propellers arranged in a "Y" shape, each powered by a separate motor.

iii) Flight Characteristics: While less common than other types, tricopters offer good maneuverability and stability. Control of yaw is managed by tilting one motor or using an additional rudder.

iv) Use: These drones are typically used for hobby flying and experimental projects but are not widely used in commercial settings. Examples: Custom-built or DIY drones.

2. Quadcopter (Four Propellers):

i) Propellers: 4

ii) Design**:** Quadcopter drones, the most popular type, feature four propellers arranged in a square or "X" pattern. Each motor powers two opposing propellers.

iii) Flight Characteristics**:** Known for their stability and maneuverability, quadcopters are easy to fly and are commonly used for both recreational and professional purposes. They adjust the speed of the motors to control yaw, pitch, roll, and altitude.

iv) Use: These drones are widely used for aerial photography, surveying, and various other commercial tasks.

Example: DJI Phantom, DJI Mavic series.

3. Hexacopter (Six Propellers):

i) Propellers: 6

ii) Design: Hexacopters feature six propellers in a circular or hexagonal arrangement.

iii) Flight Characteristics: The extra motors offer greater stability, especially in windy conditions, and increase payload capacity. In case of a motor failure, the remaining motors provide redundancy.

iv) Use: Ideal for professional aerial photography, mapping, search and rescue, and heavy-duty applications. Examples: DJI S900, Freefly Alta 6.

4. Octocopter (Eight Propellers**)**

i) Propellers: 8

ii) Design: Octocopters have eight propellers arranged in a circular pattern.

iii) Flight Characteristics: These drones are highly stable and capable of carrying heavier payloads than smaller drones. The additional motors provide redundancy, ensuring the drone stays in flight even if one motor fails.

iv) Use: Primarily used for cinematography, heavy-lift missions, and military or research purposes. Example: DJI Matrice 600, Freefly Alta 8.

5. Decacopter (Ten Propellers):

i) Propellers: 10

ii) Design: A decacopter uses ten propellers, providing increased stability and lifting power.

iii) Flight Characteristics: These drones are highly redundant and can carry extremely heavy equipment, making them suitable for tasks requiring high payload capacity and reliability.

iv) Use: Mainly used for heavy-lifting, filmmaking, and specialized industrial or military applications. Example: Custom-designed drones for specific commercial uses.

6. Dodecacopter (Twelve Propellers):

i) Propellers: 12

ii) Design: Dodecacopters feature twelve propellers to improve stability and lift.

iii) Flight Characteristics: These drones offer exceptional redundancy, making them suitable for applications where maximum reliability and lifting capacity are required.

iv) Use: Used for heavy-lift tasks, professional filmmaking, and industrial applications where the payload is significantly large. Examples include: Specialized or custom-built drones for specific commercial or industrial purposes

Table 1.1

Comparison of Drone Types Based on Propeller Count:

Type	Number of Propellers	Stability	Payload Capacity	Common Uses
Tricopter	3	Moderate	Low	Hobby flying, small payloads, experimental drones
Quadcopter	4	Good	Moderate	Photography, recreational, surveying, inspection
Hexacopter	6	Very Good	High	Professional filming, surveying, search & rescue
Octocopter	8	Excellent	Very High	Cinematography, heavy-lift, industrial, military
Decacopter	10	Excellent	Very High	Heavy-lifting, filmmaking, industrial tasks
Dodecacopter	12	Superior	Extremely High	Very heavy-lift, specialized industrial tasks

The number of propellers directly impacts a drone's stability, payload capacity, and reliability. While quadcopters are the most widely used and accessible, hexacopters and octocopters are favored for professional tasks requiring greater stability and higher payloads. Drones with more propellers, such as decacopters and dodecacopters, are used for specialized tasks demanding maximum redundancy and heavy lifting, though they come at a higher cost and complexity.

For the purpose of this project, we will be focusing on the hexacopter drone.

1.2 Advantages and Disadvantages of Unmanned Aerial Vehicles (UAVS) or Drones

1.2.1 Advantages

1) Cost efficiency

2) Increased productivity

3) Precision and Accuracy

4) Safety and Risk reduction

1.2.2 Disadvantages of Drones

1) Regulatory and Legal issues

2) High initial cost

3) Weather dependence

4) Limited flight time

1.3 Problem Statement

Civilization has progressed and man no longer needs to get involved in everything before it is done. With the advancement of technology, there are numerous ways to improve our daily living, our businesses and also our country in general. Such advancement has led to the drone technology. With the advent of the hexacopter drone technology, jobs like delivery, survey, photography, videography and so on can be carried out with little human interference thus making it convenient.

1.4 Aims and Objectives of Project

1.4.1 Aims

The main aim of this project is to create a stable drone that can be used for operations such as aerial surveys, surveys, mapping and delivery.

1.4.2 Objectives

The objectives are to:

1) Research and understand Unmanned Aerial Vehicles.

2) Understand how drones with different number of propellers are designed

3) Design an hexacopter drone capable of performing simple tasks.

4) Test and validate its flight capability and drone effectiveness.

1.5 Scope of the Project:

The scope of this project covers the classification of drones according to the number of propellers. However, we will be focusing on the the design and manufacturing of an hexacopter drone. This is a drone with six motors and propellers. The designed drone will be capable of performing simple tasks.

1.6 Relevance of the Work:

This project is relevant to different industries around the world. The stability, payload capacity, redundancy, and versatility of the hexacopter drone makes it a preferred choice for many applications. like aerial survey, infrastructure inspection, environmental monitoring, cinematography and photography, crowd monitoring, parcel deliveries and so on. The six-rotor design of a hexacopter offers greater stability compared to quadcopters (which have only four rotors). The extra rotor in a hexacopter adds redundancy. This is especially important in professional or safety-critical applications, like search and rescue operations, where a failure could have significant consequences. Hexacopters can carry more weight than quadcopters due to the additional rotors. This allows for the integration of heavier equipment.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Related Work

This research emphasizes the increasing significance and adaptability of hexacopter drones in numerous industries. Hexacopters provide distinct benefits, such as enhanced stability, higher payload capacity, and redundancy, making them valuable in sectors like agriculture, environmental monitoring, search and rescue, and cinematography. Recent advancements in autonomous navigation, battery performance, and sensor technology are further boosting their capabilities, leading to broader use in both commercial and recreational settings. Ongoing innovation in these areas is expected to broaden the application of hexacopters, especially in emerging sectors such as urban air mobility and autonomous delivery services.

Meyer and Koster (2015) investigated the use of multirotor UAVs, particularly hexacopters, in environmental monitoring tasks such as wildlife tracking, deforestation monitoring, and pollution detection. They argue that the stability and precision offered by hexacopters make them ideal for capturing detailed environmental data in difficult terrain. The paper explores how sensors and imaging technologies integrated into hexacopters help researchers collect valuable data on ecosystems and environmental changes. The work highlights the potential of hexacopters to aid in conservation efforts and environmental protection.

Zhou *et al* (2020) examines how hexacopter drones are transforming search and rescue operations. Zhou and Lin focus on the use of hexacopters for disaster relief, such as locating survivors in earthquake zones, flood areas, and inaccessible locations. They emphasize how the redundancy of hexacopters' rotor systems improves their reliability in challenging conditions. The authors also discuss the role of thermal imaging and autonomous navigation in enhancing the effectiveness of rescue missions. This work is significant for understanding the growing importance of drones in life-saving operations.

Harrison et al.(2019) explored how hexacopter drones are being used for infrastructure inspection, particularly in assessing the condition of bridges, power lines, and telecommunications towers. The paper highlights the advantages of using hexacopters over traditional inspection methods, such as their ability to reach difficult areas without scaffolding or human intervention. The authors present case studies in which hexacopters were used to inspect large infrastructure projects, demonstrating the time and cost savings they provide. This research is important for understanding the role of hexacopters in the construction and maintenance industries.

Kim and Lee.(2021) conducted a detailed comparative analysis of battery performance in various commercial hexacopters. The study explores how battery life is impacted by payload, flight time, and environmental factors. They examine the use of lithium polymer (LiPo) batteries and other advanced battery technologies in increasing the operational time of hexacopters. This paper is crucial for understanding the technical limitations of hexacopters and the ongoing efforts to improve battery efficiency for longer flight durations.

Miller and Yang (2018) analyzed the growing application of hexacopters in precision agriculture. The paper covers how hexacopters are used for crop health monitoring, soil analysis, and precision pesticide application. By using high-resolution cameras and multispectral sensors, hexacopters are able to provide farmers with detailed insights into crop conditions, allowing for more effective management practices. The study also examines the cost-effectiveness of hexacopters compared to traditional farming equipment, contributing to the understanding of how drones are revolutionizing agricultural practices.

Evans and Foster (2022) reviewed the current state of autonomous navigation technology in hexacopters. Their paper delves into the algorithms and sensors that enable hexacopters to navigate autonomously, including obstacle avoidance, path planning, and GPS-denied environments. The authors highlight key advancements in artificial intelligence and machine learning that are being applied to hexacopter drones to improve their autonomy, making them safer and more efficient for tasks such as surveying, inspection, and search and rescue.

Chavez and Gomez (2017) explored the role of hexacopter drones in the film industry, focusing on their use in aerial cinematography. The paper discusses how hexacopters have revolutionized filmmaking by providing stable and dynamic aerial shots at a fraction of the cost of traditional methods like helicopters and cranes. The authors review technological advancements in camera stabilization systems, gimbals, and payload capacities, emphasizing how these features make hexacopters the preferred choice for professional filmmakers. The research also highlights the creative potential unlocked by hexacopters in cinematic production.

Jansen.(2016). In this work, Jansen traced the early development of rotorcraft, providing a foundational understanding of the multi-rotor concept. This study highlights the gradual evolution of rotorcraft from early conceptualizations in the 1920s to modern UAVs. Jansen discusses the importance of pioneers like René Lorin, who conceptualized multi-rotor helicopters in the 1920s. This work contributes to understanding the historical context that led to the rise of hexacopters. Jansen's review lays the groundwork for how multi-rotor designs gradually gained attention for their potential applications.

Walker.(2009) focused on the analysis of UAV advancements, including the early use of UAVs for military surveillance and reconnaissance. While much of the work focuses on fixed-wing UAVs, Walker also examines early multi-rotor experiments and the challenges in developing these systems for broader use. This research contextualizes the shift towards multi-rotor drones in the civilian sector, emphasizing how the development of technology such as autopilots and remote control systems paved the way for hexacopters. Walker's work is essential for understanding the technological advancements that made hexacopters more feasible in the 2000s.

Clarke.(2014). Clarke's paper focuses specifically on the advancements that led to the rise of multirotor drones, including hexacopters. The paper examines the role of lightweight materials, advanced electronics, and better power systems (like batteries) in making multirotor systems more practical. The study also highlights the emergence of the hexacopter as a more reliable platform for carrying heavier payloads and providing greater flight stability compared to quadcopters. Clarke's work is pivotal for understanding the technical factors that contributed to the hexacopter's increasing popularity, particularly in professional and commercial applications.

Smith.(2017) discusses how companies like DJI and Yuneec revolutionized the drone industry by making hexacopters accessible to consumers and professionals alike. The study focuses on the technological advancements seen in commercial hexacopters such as the DJI S1000, which became widely used for professional aerial cinematography. Smith emphasizes how features like flight stabilization, autopilots, and the ability to carry heavy cameras made hexacopters highly attractive for industries like film production. The paper offers insight into the commercial impact of hexacopters and their adoption in both recreational and professional sectors.

Jones and Taylor (2021) analyzed the current and future developments in hexacopter technology, focusing on their growing use in industries such as agriculture, disaster management, and logistics. The paper discusses the key technological advancements driving the evolution of hexacopters, such as AI, machine learning, and autonomous flight systems. It highlights how hexacopters' redundant rotor systems and longer flight durations make them more reliable and efficient for critical missions. The work also explores the potential for hexacopters in emerging fields like urban air mobility and delivery services, making it a key resource for understanding the expanding role of hexacopters.

Liu and Wang (2018) explored the application of hexacopter drones in precision farming and agricultural monitoring. Their study highlights how hexacopters are used to monitor crop health, assess soil quality, and apply fertilizers in a controlled manner. The study focuses on the advantages of hexacopters over other UAV designs, especially in terms of their stability, ability to carry heavy sensors, and operational reliability in challenging conditions. This paper is essential for understanding the practical applications of hexacopters in agricultural industries.

2.2 History of the Hexacopter Drone

The idea of multi-rotor aircraft dates back to the early 20th century when inventors began exploring vertical takeoff and landing (VTOL) aircraft. While these initial experiments didn't lead directly to the creation of the hexacopter, they set the stage for future advancements. In the 1920s, French inventor René Lorin proposed the concept of a multi-rotor helicopter, although practical use was not achieved at that time (Jansen, 2016). In the mid-20th century, the military started heavily investing in unmanned aerial vehicles (UAVs) for surveillance and reconnaissance purposes. Although most UAVs during this period were fixed-wing, multi-rotor designs were still in the experimental phase. Nevertheless, technologies such as remote control systems and early autopilot functions began to show promise for UAVs (Walker, 2009).

In the 1990s and early 2000s, there was a significant shift toward using multi-rotor drones for commercial and civilian applications. During this time, the hexacopter design began to take shape, spurred by advancements in flight controllers, GPS systems, and lightweight batteries. Early commercial hexacopters were used for specialized tasks such as aerial photography and surveying, although the technology remained relatively niche (Clarke, 2014).

By the 2010s, hexacopter drones gained broader use, particularly in industries needing high payload capacities like aerial cinematography, mapping, and surveying. Companies such as DJI and Yuneec played a pivotal role in popularizing consumer-grade hexacopters, with models like the DJI S1000 becoming highly favored in professional photography and industrial settings (Smith, 2017). The ability to carry heavier camera equipment and maintain flight stability made hexacopters particularly attractive for film and television production. The success of consumer drones also spurred growth in industries like agriculture, where drones were used to monitor crop health and apply fertilizers from the air.

In the 2020s, hexacopters saw further adoption across various sectors, including disaster management, search and rescue, urban planning, and delivery services. Their reliable six-rotor system, combined with improvements in autonomous flight and battery life, extended their capabilities and range (Jones & Taylor, 2021). Additionally, hexacopters are becoming key players in the emerging field of urban air mobility, with potential uses in drone taxis and logistics delivery. The hexacopter drone, also known as a six-rotor drone, has evolved alongside the broader development of unmanned aerial vehicles (UAVs) or drones. The development of UAVs was primarily driven by military needs, with various forms of remote-controlled and autonomous aircraft being used for surveillance and reconnaissance. These early UAVs were mostly fixed-wing.

The advancement of computing and electronics enabled the creation of more precise and functional drones. However, the potential of multi-rotor aircraft for civilian or recreational use had not yet been fully explored. The development of multirotor drones gained traction with the introduction of lightweight materials and more advanced electronics, although these drones were still largely in the experimental stage. The real turning point for hexacopters occurred in the early 2000s, as drone technology matured and interest in multi-rotor UAVs grew for both professional and recreational purposes. During this time, the hexacopter design gained popularity due to its ability to carry heavier payloads, offer better stability, and provide redundancy compared to quadcopters, which have only four rotors. Improvements in autopilot systems, GPS, and battery technology made controlling these drones easier and extended their flight times, playing a key role in the development of both consumer and commercial hexacopters. These drones were widely used for applications like aerial photography, mapping, and surveying.

As a result of these technological advances, companies like DJI, Yuneec, and Parrot began to develop commercially viable hexacopters with advanced flight stabilization, autopilots, and better cameras, which were easily accessible to consumers. DJI's S1000 and other similar models became prominent in this period. The hexacopter, with its six-rotor design, gained attention because it offered greater lift and redundancy. If one rotor fails, the drone can still operate with five motors, making it more reliable than quadcopters in certain scenarios. Hexacopters have continued to see growing use in industries like agriculture, search and rescue, infrastructure inspection, and filmmaking due to their reliability, high payload capacity, and ability to fly in challenging conditions. With the integration of AI, machine learning, and improved battery efficiency, hexacopters are becoming even more capable, with advancements in autonomous flight and obstacle avoidance making them safer and more versatile.

In summary, the hexacopter drone evolved from early experiments with multi-rotor designs to becoming a widely adopted platform for both recreational and professional applications, thanks to advancements in electronics, battery technology, and automation. Thanks to advancements in technology, companies like DJI, Yuneec, and Parrot began developing commercially viable hexacopters equipped with advanced flight stabilization, autopilot systems, and improved cameras, making them easily accessible to consumers. During this period, models like DJI's S1000 became highly popular. The hexacopter's six-rotor design attracted attention for its increased lift capacity and redundancy. In the event of a rotor failure, the drone can continue flying with five motors, offering more reliability than quadcopters in certain situations. Hexacopters have continued to gain traction in industries such as agriculture, search and rescue, infrastructure inspection, and filmmaking, due to their reliability, large payload capacity, and ability to operate in difficult conditions. With the incorporation of AI, machine learning, and better battery efficiency, hexacopters are becoming even more advanced. Improvements in autonomous flight and obstacle avoidance are making them safer and more adaptable. In conclusion, the hexacopter drone evolved from early multi-rotor experiments to a widely used platform for both recreational and professional purposes, driven by advancements in electronics, battery technology, and automation.

2.3 Advantages of Hexacopter Drones

Some advantages of the hexacopter drones are:

1. Increased stability

2. Higher payload capacity

3. Better Lift

4. Redundancy

5. Better maneuverability

2.4 Fundamentals of major components used in the design of a hexacopter drone

1. Frame

2. Gps Module

3. Motors

4. Propellers

5. Battery

6. Sensors

2.4.1 Frame

The frame serves as the core structure of the drone, holding all the other components, including the motors, flight controller, and battery. Typical materials used for the frame include carbon fiber (valued for its lightness and strength), aluminum (chosen for its cost-effectiveness and durability), and plastic (selected for being lightweight and inexpensive). The frame must be both lightweight and durable, able to withstand the stresses from flight and potential impacts. Additionally, it must provide sufficient space to house all the internal electronics and the payload.

2-1 Frame of an hexacopter drone

2.4.2 GPS MODULE

The GPS (Global Positioning System) module provides location data to the flight controller, allowing for precise positioning, navigation, and autonomous flight capabilities such as waypoint following. The GPS module needs to be highly accurate and reliable to ensure stable flight, especially for missions requiring precise navigation, such as surveying, aerial photography, or mapping. Some GPS systems also integrate GLONASS (Russian system) or Galileo (European system) for better satellite coverage and accuracy.

2-2 The Neo 6m GPS Module

2.4.3 Batteries

The battery provides the electrical energy required to power the motors, flight controller, and other onboard electronics. The most common battery type in hexacopter drones is the Lithium-Polymer (LiPo) batteries due to their high energy density, lightweight nature, and relatively long flight times. The battery capacity (measured in mAh) and voltage are chosen based on the drone's weight, power requirements, and desired flight duration. Proper management and protection circuits are also included to avoid overcharging, over-discharging, or overheating.

2-3 A Lithium Polymer Battery

2.4.4 Sensors

Sensors used in the design of the hexacopter drone include:

1. Accelerometer: Measures linear acceleration and helps with stabilization.

2. Gyroscope: Measures rotational movement and helps with orientation control (attitude).

3. Magnetomete**r**: Functions like a digital compass, providing orientation data relative to the Earth’s magnetic field.

4. Barometer: Measures atmospheric pressure and is used for altitude hold.

4. Ultrasonic / LIDAR Sensors: Used for altitude stabilization or collision avoidance at low altitudes

2-4 An accelerometer sensor module

2.4.5 Propellers

Propellers create thrust by moving air as they rotate. In a hexacopter, the six rotors and their propellers are crucial for lifting the drone and enabling control over its movements. Propellers are typically made from materials such as plastic (which is lightweight and cost-effective), carbon fiber (known for its strength, used in high-performance drones), and composite materials. The size and pitch of the propellers are carefully chosen based on the motor's capabilities and the drone's overall design. Larger propellers with a higher pitch produce more thrust, while smaller propellers enhance maneuverability.

2-5 Propellers for an hexacopter drone

2.4.6 MOTOR

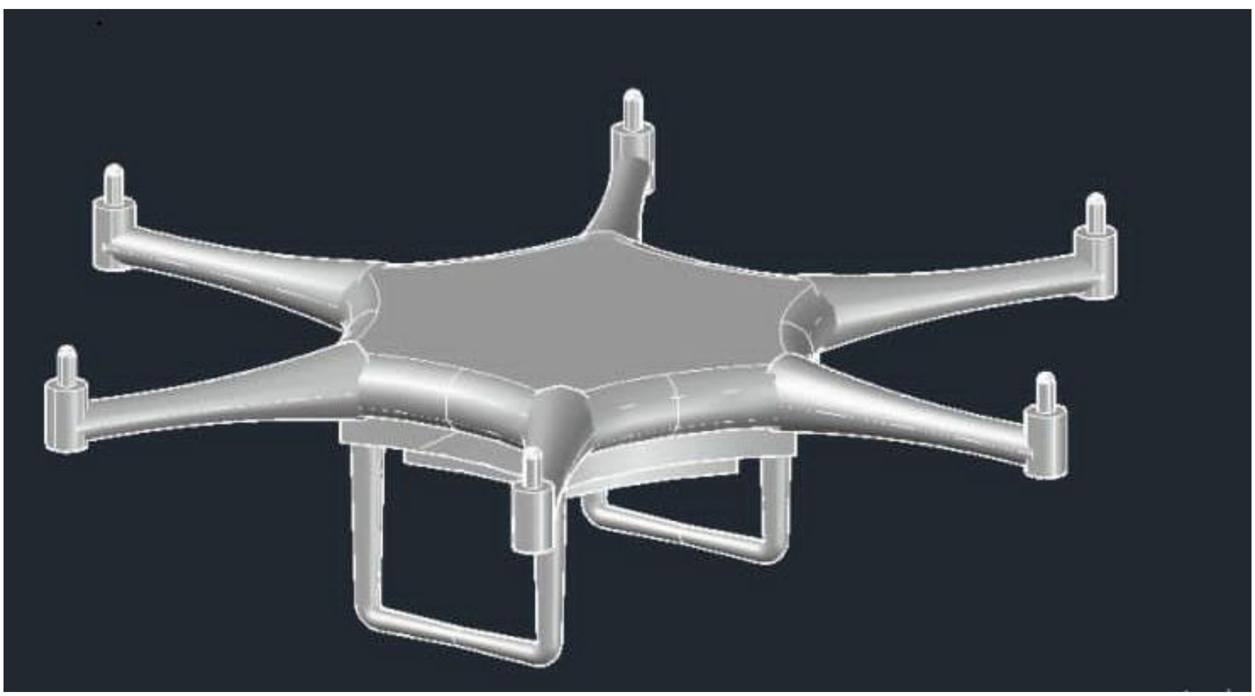
Motors provide the thrust needed to lift the drone and control its movement. Each motor drives one of the six rotors on a hexacopter. The most common motors used in hexacopters are brushless DC motors (BLDC), which are highly efficient, durable, and require less maintenance compared to brushed motors. The power and efficiency of motors are essential for lifting the drone's payload, controlling flight stability, and maximizing flight time. The motor's specifications, including power, size, and RPM (rotations per minute), are selected based on the drone's size and intended use.

2-6 A brushless motor

CHAPTER THREE

DESIGN AND ANALYSIS

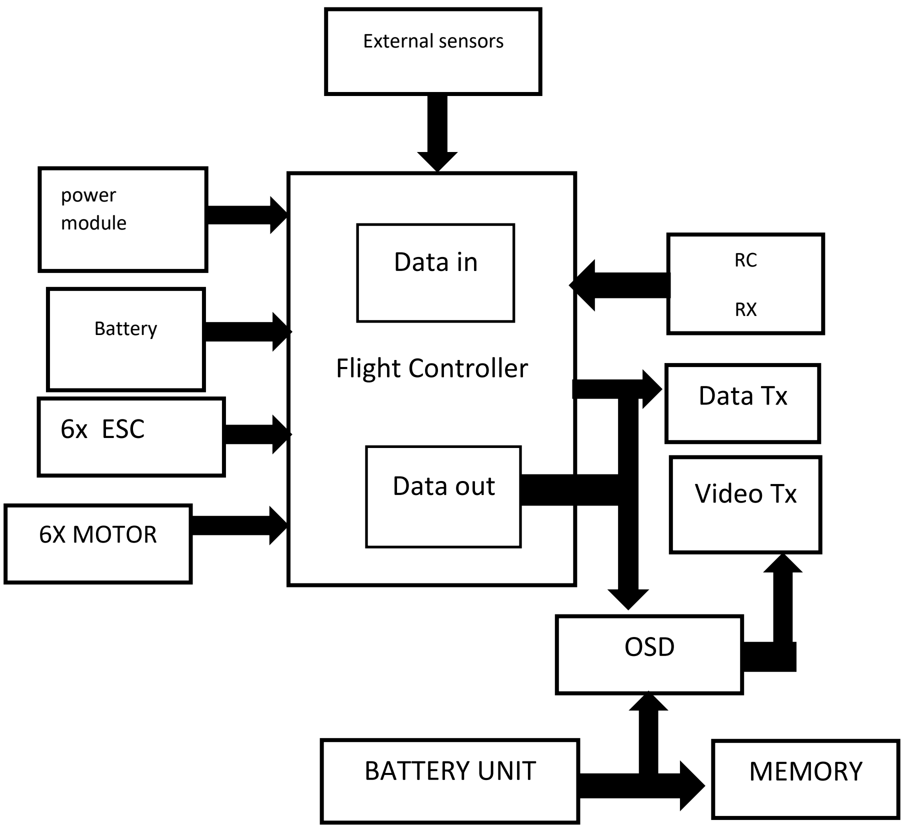
3.1 Software Design of the hexacopter drone



3-1 Cad design of the hexacopter drone

This structure was designed on the AUTOCAD software. It served as a guide to actual structure the project was desired to attain.

3.2 Block diagram



3-2 Block diagram

3.2.1 Flight controller unit

For hexacopter drones, there are different classes of flight controllers that can be used. They include:

1. Open-source Flight Controllers e.g Betaflight and ArduPilot

2. Commercial Flight controllers e.g DJI NazaV2

3. Integrated FCs (with built-in electronic speed controllers). These flight controllers come integrated with ESCs (Electronic Speed Controllers), simplifying the wiring and design. These types are often used in smaller hexacopter builds where compactness and ease of setup are important. e.g Omnibus F4

Technical specifications of these flight controllers are given below.

3.2.1.1. The Betaflight Flight Controller

I Processor: STM32F4 or STM32F7 (varies by model)

II Gyroscope/Accelerometer: MPU6000 (or similar 6-axis sensors)

III Barometer: Optional (depends on the flight controller version)

IV GPS Support: Yes (for certain models like Naze32 and F4 series)

V Firmware: Betaflight firmware (open-source)

VI Communication Protocol: Supports PWM, PPM, SBUS, DSMX, etc.

VII Input Voltage Range: Typically 4.5V to 6V (via BEC, battery input varies by model).

3.2.1.2. The ArduPilot (APM)

I) Processor: STM32 or Atmel SAM3X8E (varies by model)

II) Gyroscope/Accelerometer: MPU6000 (or other 6-axis IMU)

III) Barometer: MS5611 (high-precision barometer)

IV) GPS Support: Full GPS support (with GPS modules like uBlox NEO-M8N)

V) Firmware: ArduPilot (open-source)

VI) Communication Protocol: MAVLink for communication with ground control stations, supports SBUS, PPM, I2C, UART

VII) Input Voltage Range: 4.8V–5.5V

3.2.1.3. The DJI Naza V2

I Processor: Proprietary Naza V2 processor

II. Gyroscope/Accelerometer: Integrated 6-axis IMU (gyroscope, accelerometer, barometer)

III Barometer: Integrated for altitude hold

IV. GPS Support: Yes, integrated GPS module

V. Firmware: DJI proprietary firmware

VI Communication Protocol: Supports SBUS, PWM, PPM, and DJI proprietary protocols.

VII Input Voltage Range: 4.8V to 5.4V (via BEC)

3.2.2 Electronic Speed Controller Unit (x6)

The Electronic Speed Controller (ESC) unit **is** critical in the operation of hexacopter drones, serving as the intermediary between the flight controller and the motors. This unit consists of the electronic speed controller. It controls the speed of each motor by regulating the power supplied to them, which directly influences the drone's movement and stability. ESCs are rated for specific voltage and current levels based on the power requirements of the motor and drone. Most hexacopters use 3S to 6S LiPo batteries, and the ESCs need to handle that voltage range. Its voltage rating typically ranges from 3S (11.1V) to 6S (22.2V) for hexacopters. Current Rating for the electronic speed controller ranges from 20A to 120A depending on the motor size and power requirements.

Types of electronic speed controllers include:

1. Brushed ESC

2. Brushless ESC

3. BlhHeli ESC

3.2.2.1 Brushed ESC

This type of electronic speed controller is used for smaller drones with brushed motors (less common in modern hexacopters). Key features include:

I. Controls motors with brushes (older motor design).

II. Simpler and less efficient compared to brushless ESCs.

III. Lower cost.

Technical details include;

I. Voltage Range: 3.7V - 12V

II. Current Range: Up to 20A

III. Response Time: Moderate (slow compared to brushless ESCs)

IV. Motor Compatibility: Brushed DC motors (older technology).

3.2.2.2 Brushless ESC (BLDC ESC)

This is the most common type used in hexacopter drones today. It controls brushless DC motors, which are more efficient and durable than brushed motor. Features of this motor includes:

I. More efficient and long-lasting than brushed ESCs.

II. Works with Brushless DC motors (BLDC), offering higher power output.

III. Faster response time and smoother operation.

Technical details include:

I Voltage Range: 3S (11.1V) to 6S (22.2V) LiPo battery compatibility (common in hexacopters).

II Current Range: 20A to 120A (depending on the motor and drone size).

III Control Protocol: PWM (Pulse Width Modulation), DShot.

IV. Motor Compatibility: Brushless motors (BLDC).

3.2.3 Motor unit (x6)

This unit consists of 6 brushless motors. Brushless motors are the preferred type of motors for modern hexacopter drones due to their high efficiency, durability, and performance. Technical specifications of some brushless motors are given below. Common brushless motors and their specifications are given below.

1. T-Motor MN Series (e.g., MN3110, MN3510):

Application: High-efficiency motors suitable for heavy-lift applications, industrial drones, and aerial photography.

KV Rating: 700-900 KV.

Typical Thrust: 1000-1500 grams per motor depending on KV and battery type.

2. Emax Motor Series (e.g., Emax RSII 2207, Emax 2306):

Application: A balance between performance and efficiency, often used in commercial and professional drones.

KV Rating: 2200-2600 KV for faster and agile flight.

Typical Thrust: 1500-2000 grams per motor with a 4S battery.

3. DYS Samguk Series (e.g., 2212-920 KV, 2306):

Application: Common in both hobbyist drones and commercial-grade hexacopters.

KV Rating: 800-1000 KV for heavy-lift applications and longer flight times.

Typical Thrust: Up to 1800 grams per motor, depending on propeller size.

3.2.4 Sensors unit

This unit consists of different external sensors. The sensors include the gyroscope, accelerometer. The accelerometer measures linear acceleration along the X, Y, and Z axes while the gyroscope measures angular velocity (rotational speed) along the three axes. The barometer measures air pressure, which is used to estimate the altitude of the drone. Technical details of the barometer are as follows:

I. Measurement Range**:** Typically measures from sea level to several thousand meters in altitude.

II. Accuracy: +/- 1-3 meters in typical conditions, though this can be impacted by weather changes or other environmental factors.

III. Output: Pressure readings, which are converted into altitude.

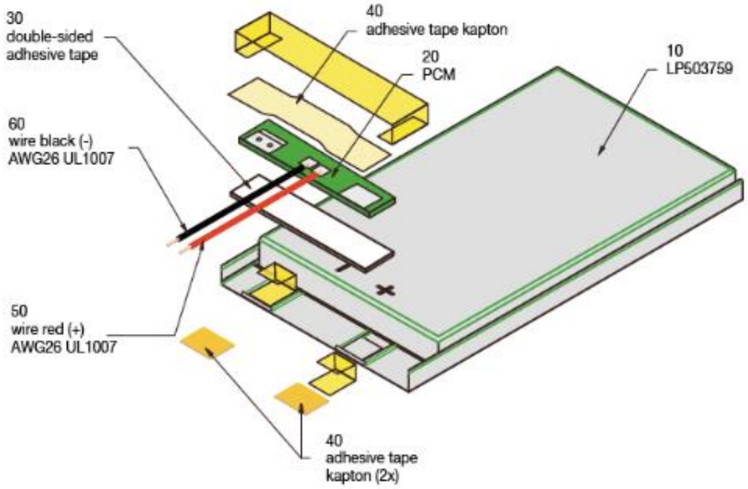
3.2.5 Battery unit

The battery unit consists of Lithium polymer batteries (Li-Po) which are the preferred batteries in hexacopter drones. Below is a table showing the specifications of the Lithium polymer battery.

Table 3.1

<table>
<tr><th>S/N</th><th>Details</th><th colspan="2">Parameters</th><th>Remarks</th></tr>
<tr><td>1</td><td>Rated voltage</td><td colspan="2">3.7V</td><td></td></tr>
<tr><td>2</td><td>Rated capacity</td><td colspan="2">2000mAh</td><td>discharge with 0.2C to 2.75V after fully charge within 1h, measuring the discharge time</td></tr>
<tr><td>3</td><td>Limited charge voltage</td><td colspan="2">4.2V</td><td></td></tr>
<tr><td>4</td><td>Internal resistance</td><td colspan="2">≤160mΩ</td><td></td></tr>
<tr><td>5</td><td>charge mode</td><td colspan="2">C.C/C.V.</td><td></td></tr>
<tr><td>6</td><td>Charge time</td><td colspan="2">6H</td><td>Standard charging 0.2C 400mA</td></tr>
<tr><td>7</td><td>Max Charge Current</td><td colspan="2">2000mA</td><td></td></tr>
<tr><td>8</td><td>Max discharge current</td><td colspan="2">Continuous： 2000mA</td><td></td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">Working temperature</td><td>charging</td><td>0~45℃</td><td rowspan="2"></td></tr>
<tr><td>discharging</td><td>-10~60℃</td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">Storage temperature</td><td>1 Month</td><td>-10~35℃</td><td rowspan="2">Charge to 40%~50% of capacity when storage</td></tr>
<tr><td>6 months</td><td>-10~30℃</td></tr>
<tr><td>11</td><td>Storage humidity</td><td colspan="2">≤75%</td><td>relative humidity</td></tr>
<tr><td>12</td><td>Weight</td><td colspan="2">Approx.45g</td><td></td></tr>
<tr><td rowspan="2">13</td><td rowspan="2">ESD ability</td><td colspan="2">Touch discharge ≥ 20000V</td><td></td></tr>
<tr><td colspan="2">Air discharge≥20000V</td><td></td></tr>
<tr><td>14</td><td>Cycle life</td><td colspan="2">300 times</td><td>capacity≥80%</td></tr>
</table>

(Mikroelectronica, 2013)



3-2 Polymer battery specifications

3.3 Design considerations

In developing the hexacopter drone, certain factors as regards parts and components in relation to the drone had to be considered. These considerations are stated below.

1. The frame is the structural foundation that supports the motors, flight controller, batteries, sensors, and payload. The design and material of the frame must ensure strength, stability, and weight optimization. Lightweight, durable materials like carbon fiber, plastic, or aluminum are used for the frame.

2. Motors and propellers are responsible for providing thrust and enabling controlled flight. Selecting the right combination is crucial for achieving desired flight characteristics such as stability, lift, and efficiency. Brushless motors are the preferred choice due to their efficiency, long lifespan, and smooth operation.

3. LiPo (Lithium-Polymer) batteries are the most common for hexacopters due to their high energy density and lightweight nature.

4. Electronic speed controllers (ESCs) should be matched to the motor specifications (e.g., current rating) to ensure proper operation.

5. High-precision dual GPS systems are often used for improved accuracy, especially in high-demand applications like surveying or precision agriculture.

6. The drone’s motors and propellers must be sized to lift and stabilize the combined weight of the drone and its payload.

3.4 Working Principle of the Hexacopter Drone

The working principle of **a** hexacopter drone revolves around the interaction between several key components: motors**,** flight controller, sensors**,** and the propellers. These components work together to achieve stable flight, control, and maneuverability. The hexacopter design uses six motors and six propellers, providing better stability and redundancy compared to quadcopters (which have four motors). Hexacopters use brushless DC motors that power the propellers. These motors are controlled by the Electronic Speed Controllers (ESCs**)**, which adjust the speed at which the motors rotate. The motors drive six propellers in total. Each propeller generates thrust by displacing air downward, creating an upward force that counteracts the drone's weight. For the hexacopter to maintain flight, the total lift from all six motors must exceed the weight of the drone. The more the motors spin, the more lift they generate. When all six motors spin at the same speed, the drone will hover at a steady altitude.

The flight controller of a hexacopter adjusts the speed of each motor to control the drone’s movement in 3D space (yaw, pitch, and roll). Yaw control is achieved by differential thrust. The opposite motors spin in different directions at varying speeds to rotate the drone. For example, if the two front motors spin faster than the back motors, the drone will rotate clockwise around its vertical axis (yaw). To tilt forward (or pitch), the front motors spin faster than the rear motors, generating more thrust at the back, causing the drone to tilt forward. To tilt backward, the rear motors spin faster than the front ones. The flight controller (FC) is the brain of the hexacopter. It uses data from **sensors** like the IMU (Inertial Measurement Unit)**,** gyroscope**,** accelerometer, barometer**,** and GPS to maintain stability and orientation in space. The flight controller constantly makes adjustments to the motors to counteract forces like wind and the drone's movements, keeping the drone stable during flight.

The Electronic Speed Controllers (ESCs) control the speed of each motor by regulating the voltage sent to them. They work based on the commands sent by the flight controller, which adjusts the motor speeds to achieve the desired flight path (hovering, turning, tilting, etc.).The hexacopter is controlled by an operator using a transmitter that sends commands to the drone. The flight controller receives these commands and adjusts motor speeds accordingly.

In essence, the hexacopter drone's working principle relies on its ability to adjust the speed of each motor to control the flight direction and maintain stability in three-dimensional space. The flight controller, with its sensors and feedback mechanisms, ensures smooth and reliable operation, while redundancy in the motor setup provides greater reliability and safety.

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULT ANALYSIS

4.1 Construction

The development of the Hexacopter drone involved coupling different parts together. The different parts of the Hexacopter drone were not readily available and to be ordered. The coupling process was hindered by some factors which include;

1. Time constraint: most of the parts had to be ordered from far away countries like China and did not arrive on time.

2. Money: the ordered parts of the Hexacopter drone were quite expensive. Also, the shipping fee was not pocket friendly.

3. Pick up location: the ordered parts of the hexacopter drone had to be moved from one pick up location to another before finally getting to the desired location. This was not convenient at all as it contributed to the wastage of time.

The parts assembled together to give the hexacopter drone includes:

1. Six propellers

2. Six motors

3. Lithium polymer battery

4. Remote control

5. Hexacopter frame

The process of coupling is as follows:

1. The remote control was opened and the left rocker was shifted to the lowest position.

2. The batteries were plugged in.

3. The connection sequence between the electrical commissioning and flight control was checked properly.

4. The left rocker of the remote control was put on.

5. The direction of rotation of motors were checked. A manual was provided, showing the correct direction of rotation of motor.

6. The propellers were then installed.

Some precautions observed during this process includes:

1. All switches of the transmitter were at the right position before connecting the battery.

2. The throttle stroke was calibrated properly for proper control.

3. The directions of the motors were checked bef0re the propellers were installed.

4. The propellers and motors were installed according to the right directions.(clockwise and counter clockwise).

4.2 Analysis of assembled parts

4.2.1 The Remote Control

During coupling, the remote control was used to check the motor steering after motor rotation. To achieve this, the throttle was long pressed in the lower right corner until the green/blue light on the flight control was steady on.

4-1 1Remote control

4.2.2 Propellers

The number of propellers needed for this hexacopter drone is six. Accordingly, six propellers were provided for installation. The direction of motor was first determined before installing the propellers. Three of the propellers were to be installed in a clockwise direction while the other three, in a counter clockwise direction.

4-2 Propellers

4.2.3 Motors

The hexacopter required six motors. The provided propellers were installed on these motors. The motors were also provided with their correct direction of installation. Half were installed in a clockwise manner and the other half in a counter clockwise direction.

4-3 Brushless motors for the hexacopter .

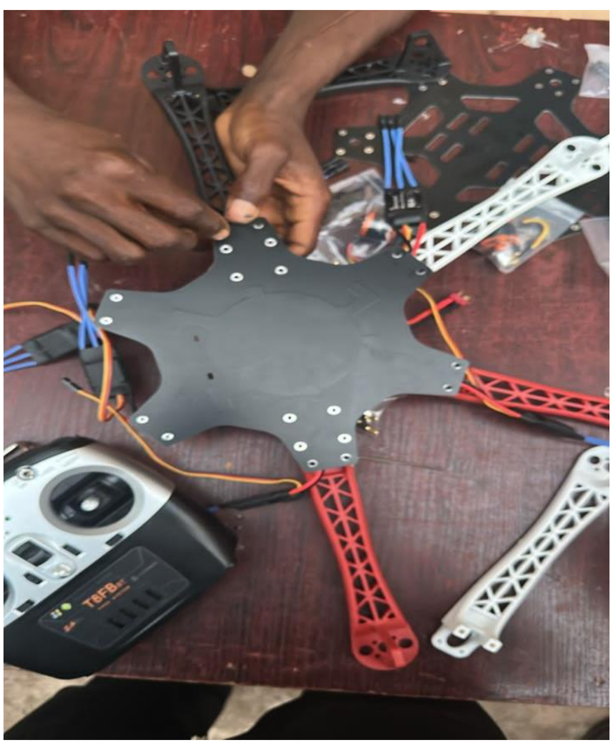
4.2.4 Lithium polymer battery

Lithium Polymer (LiPo) is common due to its high energy density and light weight. However, care is needed when handling them as they can be sensitive to overcharging, over-discharging, and physical damage. To supply the drone with power, the battery had to be plugged in before testing.

4-4 A lithium polymer battery

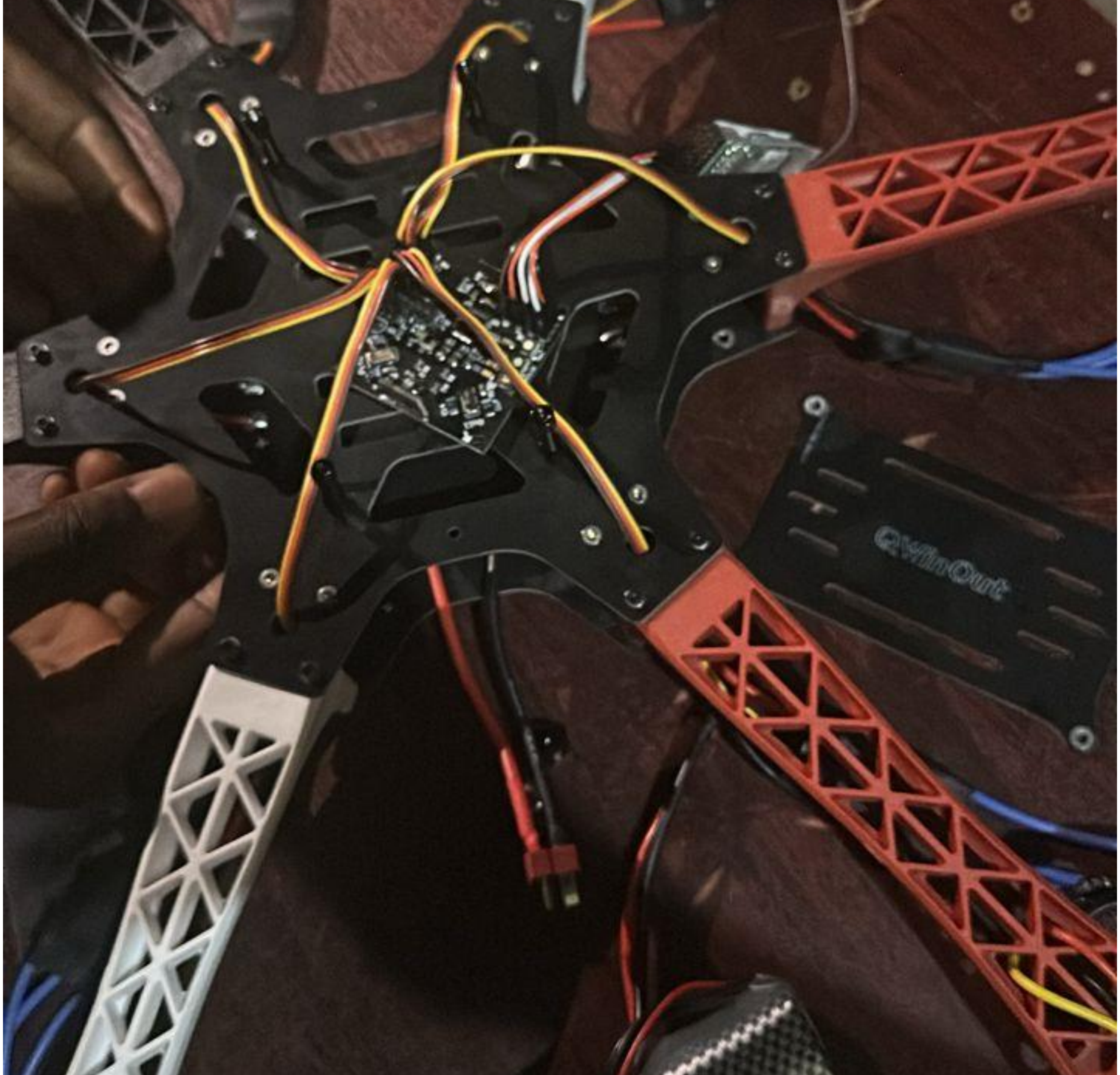
4.2.5 Hexacopter frame

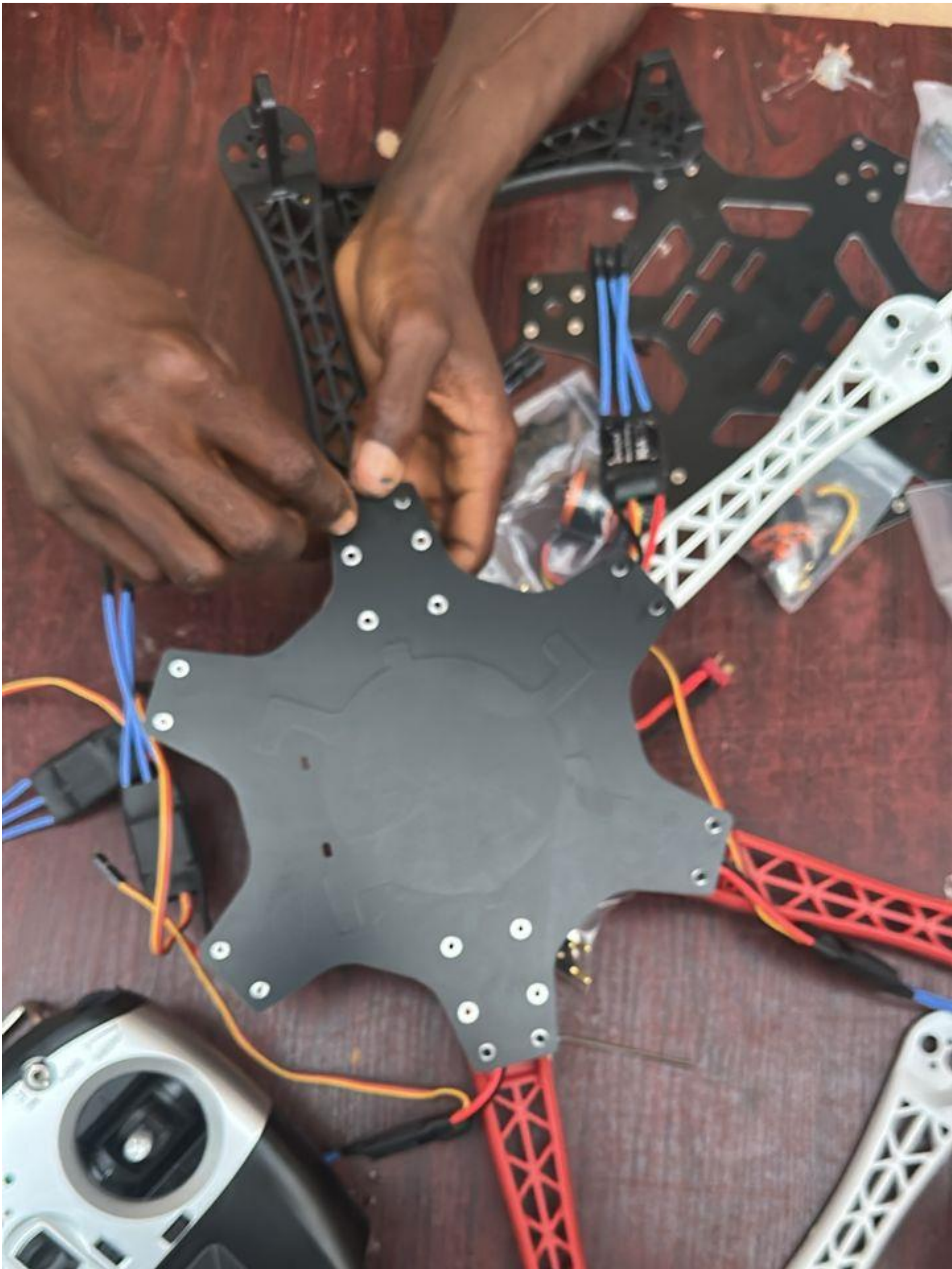
The hexacopter frame had to be assembled before it could suit its purpose. 6 slots were provided for each motor and propeller. This frame was also constructed to provide support to the battery.

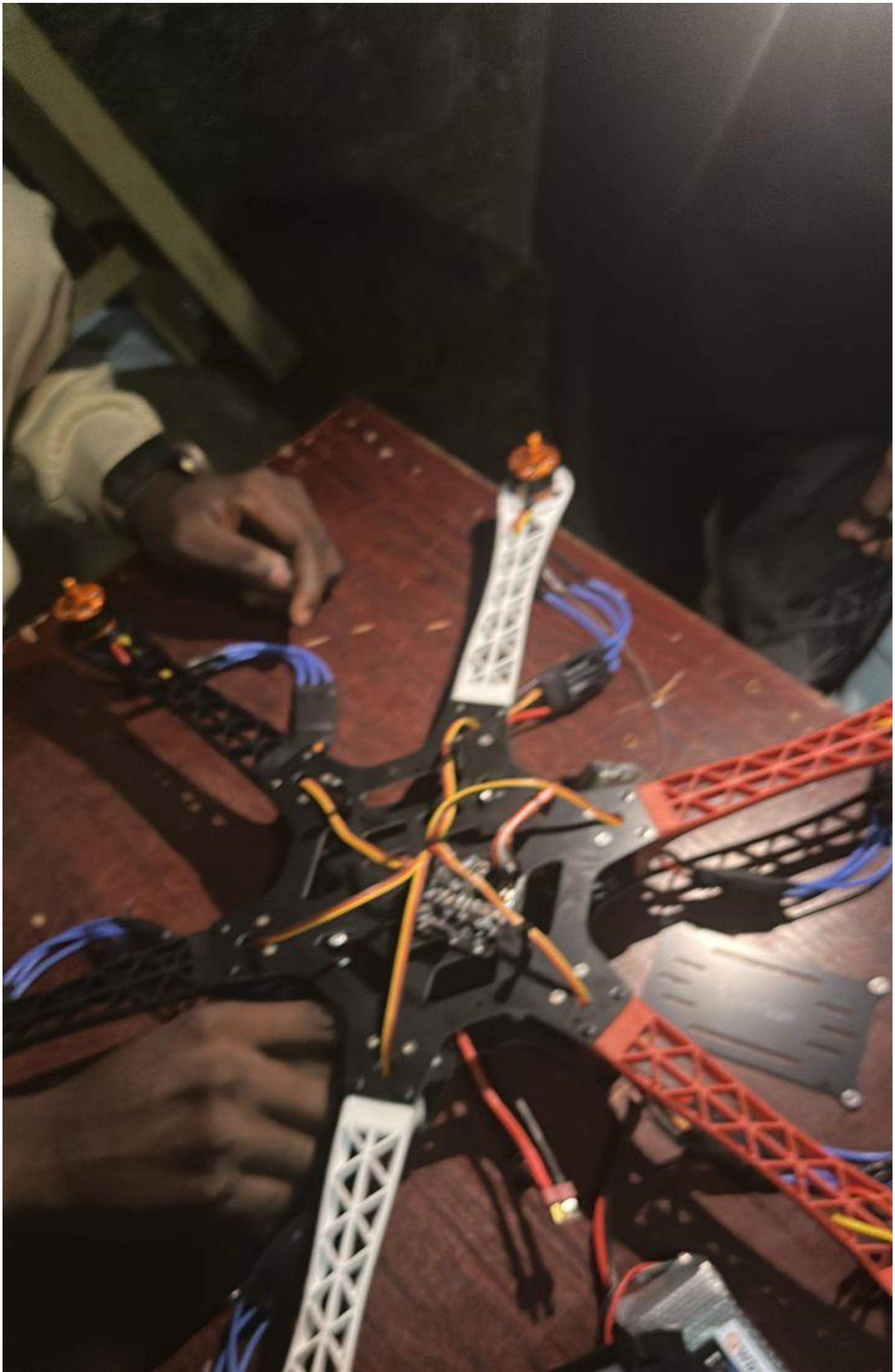


4-5 Coupling of the hexacopter frame

Below are further images showing the coupling process.


QWinOut





4.3 Testing and result analysis

After design, the following tests were carried out on the hexacopter drone to test its flight capability.

1. Motor direction test

2. Pre-flight test

3. Flight test

4.3.1 Motor direction test

This test was done to ensure each motor is spinning in the correct direction (clockwise or counterclockwise) according to the drone's design. Below is a table of the result.

Table 4.1

Motor number	Clockwise direction	Counter clockwise direction
Motor 1	Yes	No
Motor 2	No	Yes
Motor 3	Yes	No
Motor 4	No	Yes
Motor 5	Yes	No
Motor 6	No	Yes

4.3.2 Pre-flight test

This test involved visual inspection and battery check. Visual inspection includes ensuring that all motors, propellers, arms, and electronic components (ESCs, battery, flight controller) are securely mounted and properly aligned; checking for any loose connections, especially on the motor wires, ESC wires, and battery cables; inspecting propellers for cracks or damage.

4.3.3 Flight test

This test was done in three stages. The first stage was the hover test, the second stage was the short hover flight and the last stage was the basic flight test.

4.3.3.1 Hover Test

1. Without taking off, the motors were tested by arming the drone and giving throttle in small increments. This was done to ensure that the motors were spinning up evenly and the drone didn’t have issues with yaw or roll.

2. The drone was tested to check if its lift from the ground was even. This helped detect any motor or propeller imbalances.

4.3.3.2 Short Hover Flight

1. The drone was taken for a short hover in an open field.

2. The drone's stability, response to controls (yaw, pitch, roll) were tested. This was done to ensure that the drone maintains a stable hover without drifting significantly.

4.3.3.3 Basic Flight Test:

Once the initial hover test was successful, basic flight tests like forward/backward flight, turning were conducted to verify the responsiveness of the drone. These tests were performed in a safe area, away from obstacles and people. Below is a table of the result:

Table 4,2

OPERATION	RESPONSE
Forward	Excellent
Backward	Excellent
Turning	Excellent

As seen from the operational result above, the drone’s operational capacity is optimal.

CHAPTER FIVE

CONCLUSION, LIMITATIONS AND RECOMMENDATION

5.1 Conclusion

The goal of developing a Hexacopter drone was met. In order for this to be achieved, a CAD design showing the physical structure to be attained was done. Different components pertinent to achieving this structure were then assembled together. Most of the components could not be sourced locally. Some of the assembled components include the brushless motor, three pairs of propellers, lithium batteries, frame, accelerometer and so on. Special attention was paid to the quality of components gotten as counterfeit materials were going to affect the drones flight capability and operational capacity. Other important factors considered in this design were the frame design, and the balancing of the weight to strength ratio in order to ensure durability and stable flight.

Development was not complete until tests were done. Simple flight tests were carried out to test the effectiveness of the motors propellers. Also, sensors were calibrated and recalibrated till accurate navigation and control was attained. Tests results showed that this drone is effective in doing simple tasks like survey, delivery, photography and so on. By combining a methodical approach, the right components, proper testing and safety practices this project was realized.

This hexacopter drone was designed with future upgrades in mind such as additional sensors to improve performance. Recommendations were also made based on the limitations of the hexacopter drone.

5.2 Limitations

Major drawbacks of the designed hexacopter drone include:

1. The hexacopter drone involves more components than the quadcopter drone thus making it more complicated to assemble, wire and troubleshoot.

2. The hexacopter drone requires a greater lvel of technical expertise as mistakes made during assembly can lead to instability and failure.

3. The additional motors and components increases the total weight which leads to an increase in energy consumption.

4. Battery life is a limiting factor due to higher payloads. As a result, short flight times interrupt activities like aerial photography.

5. The drone is subject to environmental conditions. Maintaning balance in windy conditions is difficult.

6. Hexacopters are quite expensive leading to budget overruns thus preventing the addition of advanced and improved features.

5.3 Recommendations

The following recommendations have been made in order to improve on future developments of the hexacopter drone:

1. For better control and stability in diverse environmental conditions, more advanced flight controllers have to be used.

2. There should be an integration of a battery management system for more efficient battery use.

3. The hexacopter drone should be developed with motors that have higher thrust capabilities.

4. Water proof and weather resistant enlosures should be used to protect electronic components.

5. Batteries with higher ratings (mAh) should be used to increase the flight time.

By making these improvements, the performance, efficiency and versatility of the hexacopter drone can be improved, making it suitable for a wider variety of applications and improving its overall reliability and functionality.

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