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DESIGN AND DEVELOPMENT OF COAXIAL PAYLOAD DRONE

Mr.Benetict M[1],Jeevanandham P[2],Vinith subhash Chandra bose S[3],Vishnu S[4]

[1]Associate professor, Paavai Engineering College, Namakkal.

[2]UG, Aeronautical Engineering, Paavai Engineering College, Nammakal.

[3]UG, Aeronautical Engineering, Paavai Engineering College, Nammakal.

[4]UG, Aeronautical Engineering, Paavai Engineering College, Nammakal.

Abstract--- **In recent years, the use of unmanned aerial vehicles (UAVs) has increased significantly due to their ability to perform tasks that are difficult, dangerous, or impossible for humans to complete. One such task is the transportation of payloads over long distances. Traditional quadcopter drones are limited in their payload carrying capacity due to their design, which requires a large amount of energy to lift off the ground. To overcome this limitation, a coaxial payload drone has been designed and developed.The coaxial payload drone consists of two rotors that rotate in opposite directions, with one rotor mounted above the other. This design provides the drone with greater stability and maneuverability, allowing it to carry heavier payloads over longer distances. The coaxial design also reduces the drone's size, making it more portable and easier to transport.**

Keywords- drone , coaxial , pixhawk, stable , high weight lift , payload drone

I. INTRODUCTION

A coaxial drone is a type of unmanned aerial vehicle that features two sets of rotors mounted one above the other on the same vertical axis. This design allows for increased stability and maneuverability, making coaxial drones ideal for a variety of applications, including aerial photography, videography, and surveillance.

Coaxial drones are often used in indoor and outdoor environments where stability is crucial, as they are less likely to be affected by wind and turbulence. Additionally, the design of the coaxial rotors produces a counter-torque effect, which eliminates the need for a tail rotor found in traditional single-rotor helicopters.Coaxial drones can be designed as either multirotor or single-rotor UAVs, depending on the specific requirements of the mission. Multirotor coaxial drones are typically smaller and more maneuverable, while single-rotor coaxial drones are larger and can fly for longer durations.

Coaxial drones can be equipped with a variety of sensors and cameras, making them ideal for a range of applications. For example, they can be used for aerial inspections, search and rescue operations, and precision agriculture.Overall, the coaxial drone design offers several advantages over traditional UAVs, including increased stability and maneuverability. As UAV technology continues to evolve, it is likely that we will see more advanced and specialized coaxial drone designs in the future.

Many UAVs are designed with dual motor or coaxial propulsion systems. There are several variables to consider when designing such systems, such as relative propeller size, speed, and inter-rotor distance. Making the right design decisions allows you to build the highest performing UAV possible - in terms of thrust, torque and efficiency.We recently completed a study comparing various dual motor and coaxial rotor configurations. We compared the effect of inter-rotor distance, propeller size and relative propeller speed on total thrust and torque generated as well as propeller and propulsion system efficiency. We believe that these results are pertinent to all unmanned aircraft designers, as they can inform better vehicle designs resulting in higher efficiencyand performance.

II. LITERATURE SURVEY

B.Wang,Zhifei Hou,Wancen Wang.(2015) analysed the hover duration performances of miniature VTOL(Vertical Takeoff and Landing) air vehicles depend on the performance of the propulsion system. Based on the mass models of battery, motor and ESC(Electronic Speed Controller), and the relationship between provided force and required power of propeller, the duration calculation model of vertical takeoff and landing air vehicles was established by using the battery constant-current discharge model. The influence of propulsion parameters and payload on vehicle duration is analyzed, which would be used for preliminary design of VTOL air vehicles and components selection of propulsionsystems.

Wojciech ,Adam Bondyra, Stanisław Gardecki,Przemysław Gąsior.(2016**)** proposed a contrast Experimental Analysis of different types of propulsion systems developed for multi rotor UAVs. One of the most interesting designs is the so called X8 quadcopter, which extends original quadrotor concept to 8 motors, arranged in 4 coaxial pairs.loss of efficiency due to coaxial propellers' configuration, because the lower propeller loses thrust working in prop wash of upper propeller. This paper presents the experimental verification of performance of such propulsion systems in practical terms of designing multi rotor platforms, compared to design with 8 isolated propulsion units. In addition, its advantages versus classic quadrotor concept is shown. The series of experiments with different motors and sizes of propellers were conducted to estimate efficiency of coaxial propulsion regarding useful thrust generated by each configuration.

Xunhua Dai,Quan Quan,Jinrui Ren,Kai-Yuan Cai.(2018) proposed a practical method to help designers quickly select the optimal products of the propulsion system to maximize the multicopter efficiency under the desired flight condition. First, the modeling methods for the components of the propulsion system are studied respectively to describe the optimization problem mathematically. Secondly, methods are proposed to find optimal motor and propeller combination with the maximum thrust efficiency according to the given design requirements. Finally, factors that may affect the hovering time of multicopters are analyzed, and the optimal battery parameters are obtained for maximizing the multicopter endurance. Experiments and simulations are performed to demonstrate the effectiveness and practicability of the proposed method.

Wayne Ong,Spot Srigrarom,Henrik Hesse.(2019) design methodology for multirotor Unmanned Aerial Vehicles (UAVs). To specifically address the design of vehicles with heavy lift capabilities, and have extended existing design methodologies to include coaxial rotor systems which have exhibited the best thrust-to-volume ratio for operation of UAVs in urban environments. Such coaxial systems, however, come with decreased aerodynamic efficiency and the design approach developed in this work can account for this. The proposed design methodology and included market studies have been demonstrated for the development of a multi-parcel delivery drone that can deliver up to four packages using a novel morphing concept. Flight test results in this paper serve to validate the predictions of thrust and battery life of the coaxial propulsion system suggesting errors in predicted flight time of less than 5 percent.

This project utilized a vast range of hardware components and software platforms that were integrated into the overall design of the medical drone. It is not in the scope of the project, nor in this paper, to delve into the details and logistics of the electrical and computer engineering relationships involved in the overall design. However, in this section the use and function of the various hardware and software platforms used in the project will be explained briefly.There is an abundance of existing software platforms (Paparazzi, MultiCopter, KK, DjiNaza) and hardware components used for drone prototyping. The most common hardware components involved in prototyping include GPS and compass, flight control unit, data transmission module, data receiving module, remote controller, electronic speed control, motor(s), battery, motor power hub, servo(s), voltage sensor, current sensor, remote controller, camera, video transmission module, on screen display, power board, battery, and a voltage converter.

III. COMPONENTS OF COAXIAL DRONE

BRUSHLESS MOTOR

Brushless motors are known for their high efficiency, power, and reliability. They are also lightweight and compact, making them an ideal choice for drone applications. They can provide high thrust-to-weight ratios, which is essential for achieving stable flight and carrying payloads.

of sensors and can control the flight of a drone using GPS navigation, altitude and attitude control, and various other features. It is highly customizable and can be programmed with different software to suit specific needs.

Overall, the Pixhawk flight controller is widely used and highly regarded in the UAV industry for its reliability and flexibility.

FIGURE 3.1. PIXHAWK

PIXHAWK PX4 2.4.8 Flight Controller is a high-performance autopilot-on-module suitable for fixed wing, multi rotors, helicopters, cars, boats and any other robotic platform that can move. It is targeted towards high-end research, amateur and industry need and combines the functionality of the PX4FMU + PX4IO.

ELECTRONIC SPEED CONTROLLER

When a throttle input is received by the ESC, the MCU processes the signal and sends a pulse-width modulation (PWM) signal to the MOSFET, which switches on and off rapidly to regulate the amount of power sent to the motor. By varying the pulse width, the ESC can control the speed of the motor.

FIGURE 3.2. ELECTRONIC SPEED CONTROLLER

PROPELLER

A propeller with a diameter of 6 inches is a common size used for small to medium-sized unmanned aerial vehicles (UAVs) such as quadcopters or drones. The size of the propeller is typically indicated by its diameter and pitch, which determines how much lift and thrust it can generate.

FIGURE 3.3. PROPELLER

PIXHAWK

The Pixhawk flight controller is equipped with a variety

LIPO BATTERY

A LiPo (Lithium Polymer) battery with a capacity of 4600mAh is a relatively high-capacity battery that can provide a longer run time for your device compared to lower capacity batteries. The exact run time will depend on various factors, such as the power consumption of your device and the discharge rate of the battery.

Here are some additional details about a LiPo battery with 4600mAh capacity:

Voltage: LiPo batteries with a capacity of 4600mAh typically have a nominal voltage of 3.7 volts per cell, with multiple cells connected in series to increase the total voltage. For example, a 3-cell LiPo battery with 4600mAh capacity would have a total voltage of 11.1 volts.

Discharge rate: The discharge rate of a LiPo battery indicates how much current it can deliver at a given time. A higher discharge rate means the battery can provide more power, but it may also result in faster battery drain and shorter run time. LiPo batteries with a capacity of 4600mAh typically have a discharge rate of around 25C to 50C, meaning they can deliver 115A to 230A of current, respectively.

Size and weight: The size and weight of a LiPo battery with 4600mAh capacity can vary depending on the number of cells and the overall design. For example, a 3-cell LiPo battery with 4600mAh capacity may measure around 139mm x 44mm x 28mm and weigh around 325g.

FIGURE 3.4. LIPO BATTERY

IV. DESIGN AND DISCUSSION OF COAXIAL QUADCOPTER

DESIGN OF COAXIAL QUADCOPTER

Initially the quadcopter was build using Aluminium C-shape channel and Mica sheet ,it was unsuccessful due to the selection of C- shape channel and unavailability of square channel of 1 sq.cm. Finally the quadcopter the proposed system is used to take the application for its purpose.

The Quadcopter was build by using the components listed in previous chapter. The main frame was selected that are easily available for the development of the quadcopter. Here the base of F450 diagonal developed frame is used to build the frame. All the components are fixed on the frame.

CALIBRATION.

Esc Calibration:

As we are using PIXHAWK 2.4.8 flight controller which is programmable in the opensource software which give the platform to calibrate the Esc for the BLDC Motor. The hardware need to be connected to the laptop or PC which have the software. By choosing the COM and port that hardware is connected to the laptop/PC.

After connecting. Ensuring the propeller is detached before calibration. Throttle is raised to higher position in Transmitter. As PIXHAWK 2.4.8 comes with safety switch. It need to be trigger then after two beep sound, we need to stick down to the lowest position while doing three beep sound would occur, At last the stick raise will make movement of motor in simultaneously. Esc Calibration is done for simultaneous BLDCMotor Operation.

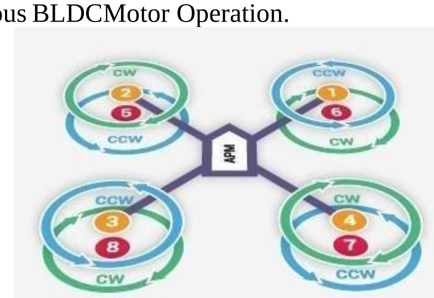


FIGURE 4.1 DYNAMICS OF COAXIAL QUADCOPTER

It was later adopted in the aerospace, automotive, shipbuilding, and other industries. CATIA enables the creation of 3D parts, from 3D sketches, sheetmetal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition.

FIGURE 4.2 UPPER ARM

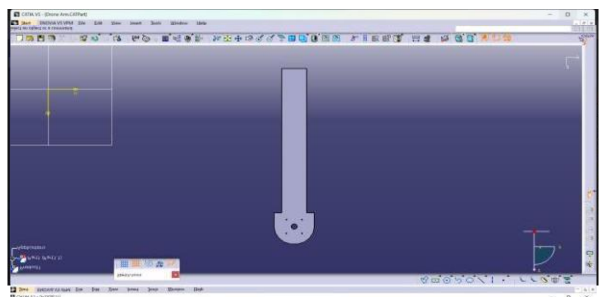
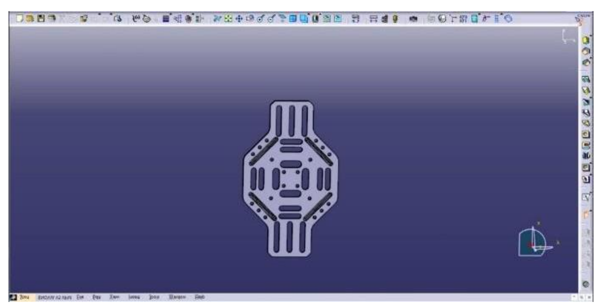


FIGURE 4.3 LOWER ARM

FIGURE 4.4 POWER DISTRIBUTION BOARD



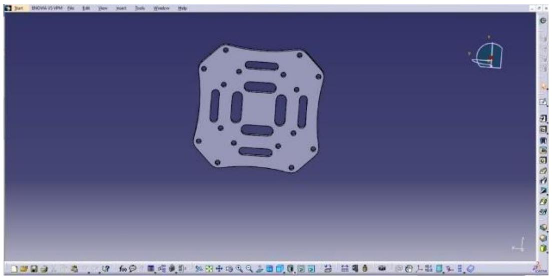


FIGURE 4.5 UPPER PLATE

V.RESEARCH METHODOLOGY AND ITS PROCESS

WORKING PRINCIPLE

The working principle of a coaxial quadcopter is similar to that of a traditional quadcopter, with the main difference being the use of two sets of propellers rotating in opposite directions. The quadcopter is controlled by varying the speed and direction of each set of propellers, which enables it to move in different directions and maintain stability in the air.

When the quadcopter is powered on, the flight controller sends signals to the ESCs to start the motors and spin the propellers. The opposing rotation of the propellers creates a stable platform that allows the quadcopter to hover in the air. By varying the speed and direction of the propellers, the flight controller can control the movement of the quadcopter in different directions, including forward, backward, left, and right.

The working principle of a coaxial quadcopter involves the use of two sets of propellers rotating in opposite directions, which allows for greater stability and control during flight. The flight controller and ESCs work together to regulate the speed and direction of the propellers, allowing the quadcopter to move in different directions and maintain stability in the air.

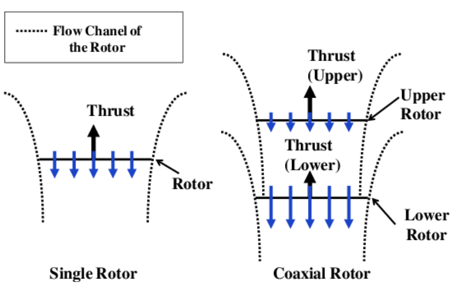


FIGURE 5.1 ROTOR SCHEMATIC DIAGRAM

LIFT PRODUCTION

In a coaxial rotor system, lift is generated by the two sets of rotors rotating in opposite directions. Each set of rotors produces lift by creating a downward flow of air, which creates an upward force on the rotors and the aircraft. The lift produced by the coaxial rotor system is proportional to the speed and angle of attack of the rotors.

The opposing rotation of the rotors in a coaxial system provides a number of advantages over a single rotor system. First, the opposing torque forces produced by the rotors cancel each other out, eliminating the need for a tail rotor or other means of torque compensation. This makes the coaxial rotor system more efficient and easier to control.

Second, the coaxial rotor system provides greater lift capacity than a single rotor system of similar size. This is because the dual rotors can produce lift more efficiently, allowing for heavier payloads and more stable flight in windy conditions.

Finally, the coaxial rotor system provides greater manoeuvrability and control than a single rotor system. The opposing rotation of the rotors allows for more precise control over the aircraft's movement, and the absence of a tail rotor eliminates the risk of a tail rotor strike during maneuvers.

The lift production in a coaxial rotor system is achieved through the opposing rotation of two sets of rotors, which provides greater lift capacity, stability, and control than a single rotor system.

VI. WEIGHT CALCULATIONDISCRIPTION

Estimating the weight of a quadcopter drone is a crucial step in designing and building a drone that can perform well and achieve the desired flight characteristics. The weight of a drone impacts its flight time, stability, and maneuverability, among other factors.

The frame of the drone should be lightweight but sturdy enough to withstand the stresses of flight. Materials such as carbon fiber or aluminum are often used for this purpose. The weight of the frame can be estimated by calculating the surface area andthickness of the frame.

The weight of the motors and propellers depends on the size of the drone and the desired performance. Larger motors and propellers can generate more thrust but also add weight to the drone. The weight of the motors and propellers can be estimated by considering the size, power, and efficiency of the components. The battery is a critical component that provides power to the motors and other electronic components. The weight of the battery depends on its capacity and chemistry. Lithium-polymer (LiPo) batteries are commonly used in drones because they have a high energy density and can be recharged quickly. The weight of the battery can be estimated by considering its capacity and voltage.

Finally, the weight of the electronic components such as the flight controller, receiver, and transmitter, can be estimated by considering their size and power consumption.

Once the weight of each component is estimated, they can be added together to calculate the total weight of the drone. The weight of the drone should be balanced to ensure stable flight, with the center of gravity located near the centre of the frame.

WEIGHT

Weight can be calculated by adding individual component weight together

Total weight (W_0) = $W_1 + W_2 + W_3 + \ldots W_n$

Total weight (W_0) = 1600g

Mass M = Weight / Acceleration due to gravity

= 1600/ 9.8

= 163.26 gs/m

M = 163 kg gs/m

FIGURE 6.1 TOTAL WEIGHT OF DRONE.

VII. THRUST CACULATION

Thrust to Weight ratio of the drone can bevaried by engaging and disengaging the Co-Axial propulsion units. The additional rotors at the down side of the frame cannot be used continuously, because the lowerpropeller loses thrust working in prop wash of the upper propeller but this offers ability to provide significantly higher thrust for the platform in smaller volume.

Thrust to Weight ratio of the Drone when only the rotors atthe top side is used,

Thrust produced with one motor and propeller combination = 800 grams

Total Thrust produced at 100% RPM = 800*4
= 3200 grams

Thrust to Weight Ratio = Total Thrust produced/ Total weight of the drone
= 3200/1600
= 2: 1

Total Thrust produced at 100%RPM (8 motors) = 800*8
= 6400 grams

Thrust to Weight Ratio = 6400/1600
= 4: 1

The Thrust to Weight ratio can be increased about 100%but the additional Co-Axial propulsion units cannot be used continuously during Hovering, because the additional Thrust produced by them requires extra 17-29% power consumption to produce same amount of Thrust, as produced by the rotors at the top side.So this decreases the redundancy of the Drone. Instead of continuous usage of theCo-Axial rotors at the down side it can be used as a Back-upduring an Emergency.
Current output of the Battery = 10,000mAh

Battery Endurance= current output from battery/Total current consumption

= 10000/96.6 A
= 10*60/96.6 A
= 600/96.6 A
= 6.21 minutes (at 100% Throttle)

current output of the Battery= 4200mAh

Total current consumption of the components= 96.6A (It includes current consumption of 8motors,8ESC)

= 4200/96.6 A
= 4.2*60/96.6 A
= 2.60 minutes (at 100% Throttle)

VIII. RESULTS AND DISCUSSION

Before conducting tests, the team made necessary assumption to obtain feasible results. Some assumptions made include: ideal weather conditions during flight, ignore force endured due to take-off acceleration, ignore drag, assume that battery charges/discharges at constant rate. Knowing the device requirements, the team set up for prototypes testing. After testing, the team reviewed the performance to see if any specifications were not met.
The design team first validated the individual components of the device before assembling the device so that a better understanding of the outcome would be hypothesized Overall, the results were as expected and produced promising numbers. It produced far greater results in correlation to the cost of production. According to the results, it is clear that the prototype satisfies the specifications and thus successfully demonstrates concept feasibility.

Total current consumption of the components= 96.6A (It includes current consumption of 8motors,8ESC,receiver and Flight controller)

FIGURE 8.1 PROTOTYPE

This project provided insight on the feasibility of the goals setout to be accomplished. The team successfully designed and built a drone with an arm attachment to enable the transportation of payload supplies.

Thus, the fabrication, design and testing of the payload dronewas successfully demonstrated and the concept feasibility of implementing payload supply delivery drones in the deliverysystem of the company.

PAYLOAD LIFT

The payload we are carried out through this drone has made several testing of motor thrust calculations . Each motor can carries about 800 gram of payload at its maximum level of thrust and if eight motors works simultaneously it will carry 6.4 kg . Out of which 1.6 kg is drone weight and remaining is a payload weight.

Thus the drone has capability of carrying payload is between 4 to 4.6 kg

IX. CONCULSION

In conclusion, the development and design of coaxial payload drones have come a long way in recent years, and the technology has the potential to revolutionize a wide range of industries. Researchers have explored various designs and control strategies for coaxial payload drones and developed prototype drones for specific use cases.

They have also developed various payload delivery mechanisms to ensure accurate and safe delivery of payloads. However, there are still some challenges and limitations that need to be addressed, including limited payload capacity, battery life, and the need for advanced control systems to ensure stable flight.

Looking to the future, there are several exciting directions for the development of coaxial payload drones. The use of advanced materials and sensors for obstacle avoidance could help to reduce weight and increase payload capacity. Furthermore, the integration of autonomous control systems could further enhance the safety and reliability of coaxial payload drones.

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