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DESIGN AND FABRICATION OF HEAVY LIFT DRONE

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Abstract
Unmanned Aerial Vehicles (UAVs) are transmitted into multirotor UAVs having the capability of lifting the payload and are also being used for the surveillance of unapproachable areas. The payload and programming capabilities of quadrotor UAVs are frequently limited. Unmanned aerial vehicles have recently piqued the curiosity of the research community (UAVs). Different multirotor UAV configurations were investigated in this study to determine the ideal configuration for a compact but heavy-lift multirotor which can sustain a payload of 50 kgs. It has been discovered that coaxial/overlapping designs can boost payload while maintaining a modest dimension. With the right selection of rotor plane angles, thrust might be boosted by up to 90% for overlapping systems. The rotor thrust in a coaxial configuration was determined to be 76 percent that of an independent rotor. The ability to develop a highly maneuverable and reliable vertical take-off and landing (VTOL)-UAV is a significant contribution to the field of aerial robotics because the possibilities are endless in practical applications, an operator controls the UAV's position in space using a remote server using sensory cues from an image acquired, while the angle is automatically stabilized using an onboard controller. The attitude regulator is critical when the pilot executes the desired movements because it allows the vehicle to maintain the appropriate orientation and so avoids the vehicle turning over and crashing.

Keywords: Aluminum; Analysis, Carbon fiber, design, Frames, Multirotor, Payload.

1. INTRODUCTION

Diverse wireless drones are commonly used for various purposes. Blades on multirotor are typically fixed pitch. Due to the unavailability of flight controls in ancient times, work on proving the concept could not be completed due to the instability of the multirotor. Multirotor development advanced with the introduction of MEMS sensors, motors, electronic speed controllers (ESCs), and Li-Po batteries. These are radio-controlled drones that can carry up to two kilograms of cargo during flight. A multirotor is now employed for a variety of purposes. Surveillance, rescue operations, and other tasks are among the multirotor applications. Due to developments in inflight controls and ESC, multirotor drones are more stable. The current research platform is Multirotor. When it comes to multirotor configurations, the quadcopter configuration UAV has a strong frame structure that is also simple in dynamics. When used in the media, hex copters and octocopters lift huge payloads for aerial photography or broadcasting. The above UAV designs were examined, and it was discovered that the hex copter configuration is superior in terms of rescue and surveillance activities.

Drones and quadcopters have a fascinating history. With the aid of superior computer engineering and technology, they have progressed in incredible ways. Armed forces were the first to employ drones. These vehicles were first developed for military use by the Austrian army. In 1849, the Austrians attacked Venice with explosive-filled air balloons. A few of these balloons operated, while others were blown back into Austrian land by the wind, indicating that they had potential. After WW1, unmanned aircraft began to appear. One of these airplanes was Larynx. It was a small monoplane that could fly 2 on autopilot after being fired from a battleship. The US and British armies quickly created plenty of other automatic planes. Reginald Denny, a well-known Hollywood actor, designed the first mass-produced aircraft. He founded Reginald Denny Company to pursue his passion for remote-controlled drones. This firm created the radio plane, which he later refined for the US army during WWII. The US military experimented with drones and built a variety of airborne torpedoes as a result. During the Cold War, the US army utilized these planes as target drones. These drones could also collect radioactive information. The Quadcopters were one of the first vertical take-off and landing (VTOL) aircraft. Previously, tail rotors were employed to offset the torque created by a single main rotor. This was a waste of money and time. Engineers developed quadcopters to tackle the challenges that helicopter pilots had when making vertical flights. The Omnichen 2 was the very first quadcopter. Etienne Omnichen invented it in 1920. This airplane performed over 1,000 successful trips and flew a distance of 360 meters. In 1956, the Convert a wings Model A quadcopter was released. George E. Bothezat designed this quadcopter. Convert a wings' Model A quadcopter was the first to use propulsion to control a plane's yaw, spin, and roll. This same Curtis Wright V27 had been designed by Curtis Wright Company in 1958. In terms of technology, Multicopters and drones had already come a long way. In the last ten years, companies such as Heli-Max, Blade, Walker, Parrot, as well as DJI it has devised micro and nano drones with cutting-edge computer media for aerial photos and flight management.

Multirotor are categorized and called based on the number of motors or blades they have. A quadcopter refers to a drone with four motors. Because there are so many different combinations, the performance of the motors varies as shown below:

Figure 16: Bi-copter Configuration[1]

Figure 17: Tri-copter Configuration[2]

Figure 18: Quadcopter Configuration[3]

Figure 19: Penta copter Configuration[4]

Figure 20: Hex copter Configuration[5]

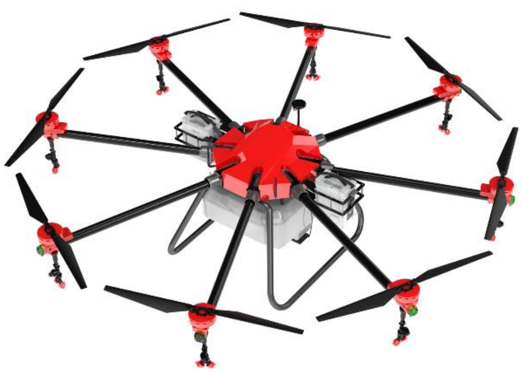

Figure 21: Octocopter Configuration[6]

2. Literature Review

Quadcopters or simple quadrotors are rotorcraft having four lift-producing propellers. Two propellers rotate in a clockwise manner and the other two rotate in an anticlockwise direction. Propeller speed is an important factor in controlling rotorcraft, and increasing the propellers' relative speed is an effective way to do it. The idea of quadrotors is not new, however current multirotor is often unmanned developments in the field of compact inertia measuring units (IMUs). In addition, brushless high-speed motors are readily available, and their power-to-weight ratio is quite high. The quadrotor's design and construction have been greatly simplified and made more maintainable because of advances in Li-polymer battery technology. In the proposed work, quadcopter dynamics are modeled using a mathematical model. Hovering control is made easier by applying momentum theory in which the air friction and gyroscopes are ignored, which results in a simpler model that can be used to create the quadcopter's control system. The suggested model is non-linear because the rotary dynamics are a function of the square of the motor inputs. Different equations are used to keep the system's role, pitch, and yaw capabilities in balance with the inputs it receives from the environment. The yaw angle produced by the mechanism and the motor speed is also linked[7].

As a result of this study, a quadrotor aircraft (VTOL) has been developed that is capable of vertical takeoff and landing. This study takes a look at control architecture, which includes a vision-based control mechanism. Quadrotors have caught the interest of both the military and control community owing to the complexity of their dynamics and the advantages they offer over conventional air vehicles. The gyroscope and the strategies used to control it are explored in the proposed model. A stabilization control algorithm for a quadrotor has been presented in this paper, which summarizes previous research on the subject. The controller's primary objective is to move the multi-rotor in the x, and y coordinate axes by controlling pitch and roll angles, while also controlling elevation using thrust actuation. Quadcopter yaw angle can be controlled independently by the controller. Finally, it is demonstrated and practiced that a quadrotor having an onboard camera can follow the marking on the ground and hover over that pattern that the desired altitude using vision-based control. [8]

In this article, a decomposition strategy is utilized to construct a real-time filter that estimates the height of a tiny four-rotor helicopter. Measurements from an onboard computer vision system and three-axis gyroscopes are used to create an instantaneous real-time filter. Simulink was employed to design the code and space to apply the three-component decomposition approach to the control computer processor. Low-frequency vision measurements and gyro measurements are combined to get the estimated angle. Gyro drifting and low data rates and delay in vision measurements are eliminated from the ideal estimate, which is more accurate [9].

A concept of the dynamics of the X4-flyer, a four-rotor (VTOL) vehicle, is presented. For quasi-stationary flying circumstances, the model combines airframe and motor characteristics, gyroscopic effects, and aerodynamic effects as well related to the rotors. For configuration stability of quasi-stationary flying situations, a novel control approach is provided. Splitting the complete body (airframe) dynamic from the actuator dynamics and generating independent control is the strategy utilized. Using Lyapunov functions for synchronous machines and then constraining the disturbance error due to interaction, considerable practical stabilization of the entire system may be achieved [4].

The main focus of this study is an unmanned aerial vehicle (UAV) having non-planar rotor pairs, which uses a test rig and a wind tunnel to investigate its aerodynamics. Face-to-face (F-F) and back-to-back (B-B) non-planar rotary pairs are studied at variable disc plane inclination angles varying from 0° to 50° and transverse rotor spacing ranging from 1.0 to 1.8 times rotor diameter. Non-rotor pairs are also tested inside a wind duct at varying wind speeds, varying from 0 to 4m/s, to examine the effects of air on them. The results of the experiments show that the overall aerodynamic performance of two adjacent non-planar rotors is significantly impacted by significant aerodynamic interference. Using the proper adjustable angle and rotor spacing, on the other hand, can improve aerodynamic performance. Aerodynamic performance suffers when rotors are spaced closer together, but wider rotor spacing and larger tilt angles often raise the total thrust of rotor pairs. The design specifications of non-planar rotating pairs are severely impacted by wind, resulting in a significant reduction in thrust and efficiency. In comparison to the F-F rotor pair, the B-B rotor pair's aerodynamic performance decreased significantly with wind speed because it is more susceptible to wind disturbance [5].

Unmanned aircraft (UAVs) of the quad-robot type (QRT) has been created for speedy detection and monitoring of situations in a disaster setting, such as interior fire spots. An integrated controller, an Inertial Guidance System (INS) with three rate accelerometers and gyroscopes, CCD (Charge Coupled Devices) cameras with cordless transmission broadcaster for observing, and an ultrasonic distance sensor for controlling height are all included in the UAV. This paper focuses on accurate modeling and stable flight management of QRT UAVs. In both the referencing and body frame coordinates, a comprehensive dynamic model of a QRT UAV is generated. For robust hovering control, a disturbing observation (DOB) based controller based on the resulting dynamic models is also provided. DOB's control input allows for the employment of simple equations that fulfill precisely computed dynamics. Under the use of DOB and a vision-based localization approach, the created hovering robot demonstrates reliable flying performance. Even if a model is inaccurate, the DOB approach may build a controller by considering the portion of the faulty model. Eight IR (infrared) infrared ionic distance sensors help the UAV avoid obstacles. This type of micro-UAV may be employed in a variety of disaster surveillance domains without endangering humans in a hazardous environment. The suggested control algorithm's performance is demonstrated by the experimental findings [6].

Platforms, control stations, payloads, and sensors constitute Unmanned Aerial Vehicle (UAV) systems. Advanced flight controls are needed to offer the amount of autonomy required to achieve mission objectives while also maintaining round-the-clock reliability. There will be a study of existing systems, with a concentration on airframes. Specific mission goals and aircraft functional properties may provide useful information for control system designers to customize their systems to the specific applications required. Unmanned Air Vehicles come in a variety of configurations, from traditional fixed wings to novel shrouded coaxial rotary and tiltrotor designs. For waypoint maneuvering, navigation and guiding, and autonomous takeoff and landing, each configuration have its own set of control needs. Innovative high-risk designs necessitate ever-more complicated flight control mechanisms that are both cost-effective and reliable. The most difficult problems for automatic control designers working in the UAV domain will be autonomous landing and transitional maneuvers from vertically to horizontal flight [7].

The formation control law is used to govern a bunch of four quadrotors in three dimensions in this research. Three-dimensional formation control methods have caught the interest of both the remote sensing community and its applications. The quad-rotor has also gained a lot of interest since it can hover, take off and land vertically. We apply a three-dimensional formation control law based on inter-agent distances. The Euclidean coordinate system is directly under the jurisdiction of the Euclidean coordinate system. We apply the control rule from a time-based derivative of Euclidean distance matrices with the group's distance matrix as a result of the group's revelation. Assuming that initial and targeted formations are not collinear and that the informational graph is completed, the group's desired formation is asymptotically stable, while all square inter-agent errors exponentially lowering to zero. The formation controlling of 4 quad-rotors in three dimensions is stable, according to simulation results, and it supports the control rule [8].

We analyze three control strategies in this paper: Nested Saturations, Back stepping, and Sliding Modes. When utilizing visual feedback, the main objective is to determine the optimal control technique for maintaining the location of a quadrotor. We present a technique for determining both translational speed and the UAV's 3D location in a local frame. In real-time experiments, the recommended controllers were installed and tested. The generated findings show that such techniques may be used to enhance the performance of a quadrotor. To maintain the UAV's attitude steady, control algorithms were put aboard. All control methods get the vehicle's Euler angles very close to the target values. When compared to other current controllers, the nested saturation control technique is the ideal solution for our system, since it improves the vehicle’s behavior while lowering energy usage [9].

This paper identified a navigation system for unmanned aerial vehicles (UAVs) in certain situations. A maneuverable quad-rotor UAV's route planning seems to be using a limit-cycle navigation idea based on the limit-cycle properties of a second-order nonlinear function. In addition, the three-dimensional limit-cycle approach for trajectory tracking is extended from the two-dimensional limit-cycle approach. Quad-rotor aircraft dynamics are also investigated in implementing an autonomous flight system that avoids fixed objects. Furthermore, shown in the simulation results are the efficiency and advantages of the proposed autonomous path planning method. Simulation results revealed a way to overcome local minima and undesirable effects caused by potential field methods by adjusting their avoidance circles' radius and direction. With the addition of the three-dimensional space limit cycle approach, the UAV was also able to prevent all obstacles without colliding. We tested the advantages of the suggested technology in simulations, but there are a variety of real-world scenarios that might cause the autonomous flight system to fail. These include severe winds that can render the quad-rotor UAV uncontrolled and obstructions that move unexpectedly, potentially causing crashes [10].

This paper presents the notion of control and its first application on an unmanned automated quadrotor aircraft. This is a back stepping-based centralized embedded model-based control method developed on quadrotor hardware that contains an integrated onboard computer, inertial sensor unit, as well as other elements that make it appropriate for the use of an indoor positioning system and a current wireless communication network. This realization is a significant step in the development of a more complex UAV that is compatible with practical applications; it aims to clarify control principles, gain an understanding of overcoming control issues, and build skills for future realization development [11].

Four-rotor micro helicopter’s dynamic properties were experimentally defined in this research. Several phenomena, including gyroscopic effects and aerodynamic friction, are incorporated into the modulization approach to generate an acceptable model for identification and control synthesis. In a closed loop system with the same controller, a comparison of simulated and actual systems is done. The findings suggest that the dynamic model was well estimated. The practical detection of a quadrotor UAV is discussed in this research. The system's entire model is created by using Newton’s formalism and represented in a format that allows the identification of the relevant dynamic parameters in the first phase. We used a series of trials in the second stage to create a database that the identification algorithm needed to figure out the mode parameters. A similar PID controller was deployed to the predicted model and the actual system to verify the model generated through parameter estimation. The regulatory test results reveal that the hypothesis is closer to the actual one [12].

For decades, unmanned aerial vehicles (UAVs) have captivated the curiosity of the control and commerce communities due to their benefits over manned systems. The non-linear mathematical modeling of the quad-rotor unmanned aerial vehicles is the main focus of this research. For flight testing, there is also a flying mill. Linearized models developed in the quasi-LPV or Jacobian manner can be utilized as a preliminary step for H ∞ loop shaping-based robust control design. An H∞ loop-shaped flight controller is devised for position control based on such a nonlinear model. The quadrotor UAV Dragan flyer III presented nonlinear modeling. A flying mill was proposed, which is utilized for test flights and parameter identification. For position control, an H∞ loop shaping flight controller is created using this nonlinear model. The simulation results show that it is stable, has good reference tracking, and can reject disturbances [13].

Configuration	Material	Motor
Quadrotor (+)	Aluminum	BLDC
Quadrotor (X)	Carbon Fiber	BLDC
Hexacopter	Aluminum	BLDC
Quadrotor	Carbon fiber	BLDC
Octocopter	Carbon fiber	BLDC

Table 4. Comparative Analysis

3. STRUCTURAL ANALYSIS OF ARM OF MULTIROTOR

The employment of small unmanned air systems, sometimes known as drones, Unmanned Aerial Vehicles (UAVs), or Unmanned Aerial Systems, has resulted in significant progress. Because this system has so many components, considerable research has been done on new UAV applications, control optimization, Endurance Limit Enhancement, GPS, Autopilot, and so on. A minor amount of research has been done on the structural components of hex rotors. The structural analysis must be completed to achieve High Endurance. Multirotor has a lightweight frame, high-thrust motor landing gear, and a standard structural design. Structural analysis of the arm of a multirotor with a motor mounted is urgently required. Hex rotor Carbon Fiber Arm Structural Vibration Analysis, as the arm is affected by multiple structural loads due to the high RPM of the motors. The experimental and numerical vibration study of a Hex rotor Arm and subordinate structure is discussed in this work. This study examines the vibration factors that affect the Hex rotor, as well as experimental modal analysis of the carbon fiber arm of the Hex rotor. The collected data will reveal a low-vibration zone, allowing other instruments to be mounted for better functioning.

SOLIDWORKS 2015 x64 Premium Edition analyses all of the model's components. The multi-copter's arm is simulated in this edition with some boundary conditions. We can estimate stress, strain, and the safety factor with the help of these analyses, and we can optimize our model's performance. The model is weak in the highlighted area of the model in this static analysis, and extra material should be applied in that area to prevent failure. The element has a volume of 22.94 percent. Extra resin and fiber coatings should be put in this area to make it exceptionally strong and able to withstand a considerable amount of weight. A particular amount of load is given to the motor mount in this static study. The motor mount has the largest displacement, which is 0.001034mm. According to the results, the model has a very minimal amount of displacement. The arm has a minor displacement, indicating that it is safe, and there is no substantial displacement, indicating that our design is safe based on these data. When a given amount of load is applied to the motor mount, the body will hold up to almost 2.4 times the applied load, according to the static structural analysis of the arm and mount. That signifies that the body's safety factor is 2.4. The ratio of the ultimate load to the applied load is known as the factor of safety.

This helicopter's dynamic model is essentially a 3D rigid body developing under the influence of a primary force and three moments. As indicated in Fig. 1, let I = Ix, Iy, Iz signify earth fixed reference frame. This is a right-handed orthogonal axis system, with the origin at the center of gravity of the helicopter at the start of the motion. I am considered the inertial reference frame under simplified conditions. Let B = Bx, By, Bz be a body-fixed reference frame that is a right-handed orthogonal system with the origin at the center of mass of the helicopter. The axes of the B-frame are thought to correlate with the body's major axis of inertia

Figure 22: Earth fixed reference frame and body fixed reference.

Euler-Lagrange equations can be applied to get the complete mathematical model of the full rotorcraft. Furthermore, because it has no coupling factors, the vehicle dynamics may be divided into translational and rotational dynamics The final attribute also aids in the classification of the generalized forces operating on the vehicle into two categories, the first of which is made up of translational forces and the second of which is made up of rotating torques of motion, as discussed below.

Thrust is the term used to describe the force produced by a rotor. The vector push should always be perpendicular to the rotor disc and directed upwards.

4. RESULTS

The results of this analysis are 11.073 MPa, 15.7 mm, and 0.004 in terms of maximum stress, displacement, and strain. Maximum stress, displacement, and strain are depicted in Figures 6, 7, and 8, respectively. Following the modeling of the drone body, it was discovered that the majority of the tension was generated in the y portion of the arm. Von Mises's stress is indicated in this image, which is created all over the drone body. This stress value is less than the material's maximum strength of 32.2 MPa. This stress value yields a FOS (factor of safety) of 2.91, which is within my targeted factor of safety range of 2.5 to 3.

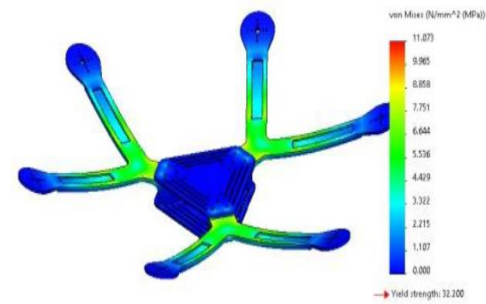

Figure 23: Maximum stress

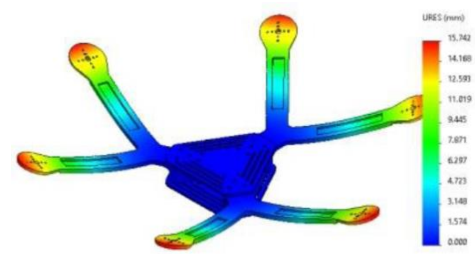

Figure 24: Maximum strain

The impact analysis was carried out to determine the drone body frame's durability. Impact analysis is carried out in two iterations, following the first iteration is 3 m in height and the second iteration is 5 m in height.

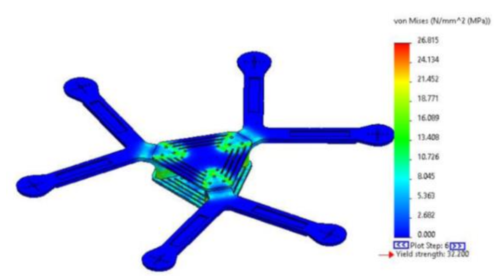

Figure 25: Impact analysis

Solid works simulation tool was used to do the impact study. The drop test was conducted at two distinct heights of 3 and 5 meters. The findings of the impact Figure 6: Maximum stress concentrated areas

Result of impact analysis for the height of 3m 22 study suggest that the majority of the stress is created at the bolted component of the assembly. The maximum stress was 29.487 MPa at a drop height of 5 meters, which is less than the ultimate tensile strength. As a result, the design was secure. The drone body was constructed using the following three materials: ABS, CF-ABS, and GF-ABS. UTM was used to test the ultimate tensile strength of the three materials mentioned above. The tensile strength of GF-ABS was found to be the highest (46.7 MPa), that of CF-ABS was intermediate (32.2 MPa), and that of ABS was the lowest (29.7 MPa). However, the GF-ABS was found to have issues with warping and nozzle jamming. CF-ABS was the next best option. Different types of patterns were subjected to static structural analysis. The best factor of safety was achieved by using a rectangular 3mm deep slot layout (2.91). Impact stress analysis in Solid Works was used to conduct the drop test. At a drop height of 5 meters, the maximum stress was 24.81 MPa, which is less than the ultimate tensile strength. As a result, the design was secure to carry a payload of 50 kgs.

5. CONCLUSIONS

The design and analysis of a multirotor UAV have been completed successfully. Our design for this project is incredibly aerodynamic and small. We conducted structurally and flow simulation analyses, among other things. We obtained a very satisfying and enjoyable result based on the analysis results. Our project is based on rotor vehicles, which we used to design this new UAV; there are far too many drones in use these days in every industry. The primary goal of this UAV is to replace outdated technology. Our design has the potential to produce superior results and performance. In comparison to other drones, our proposal has an extremely modest budget. It compresses all of the features found in other drones that are quite expensive. It is primarily designed for military operations to offer the most up-to-date information on the battleground and to carry out various operations on the battlefield. It has a night vision camera and a duplex communication system that allows it to work at night and communicate information to other people in real-time. The project's future goals include developing a thermal sensor camera, increasing the UAV's flight time, and improving performance. This UAV could be utilized for both defense and civil purposes in the future

NOMENCLATURE

UAV	Unmanned Aerial Vehicle
CF	Carbon Fiber
VTOL	Vertical Take-Off and Landing
IMU	Inertia Measuring Unit
Li-Po	Lithium-Polymer
IGS	Inertial Guidance System
ESC	Electronic Speed Controller

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