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DESIGN OF DRONE FOR CROP AND VEGETATION MONITORING

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Abstract

Crop and vegetation monitoring are an important concern for many. These applications are usually accomplished using remote sensing. The remote sensing application involves use of satellite or aircraft surveys in the existing system. These applications involve higher capital cost and a large distance between the target and appliance. This paper is considering the design of a multirotor drone for crop and vegetation monitoring. The drones can capture images from the closer proximity and have lower capital cost. The multirotor drone is selected because it has hovering capabilities. The component selection and structural strength is an important concern of this design. The selected payload of gimbal and camera is tested against the frame structure and the component selection is carried out using the procedure and iterations. The CAD model designed in CATIA V5 and using the same parameters for PID control equations are obtained. The analysis is done in static structural module of ANSYS 19.2. The designed drone is structurally stable and has 3:1 thrust to weight ratio. While the motors selected has the maximum thrust capacity of 2216 grams per motor which can be utilized when the payload is modified.

Index Terms: *drone, UAV, Quadcopter, monitoring, camera, gimbal.*

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1. INTRODUCTION

The multirotor drone usually characterized by number of rotors (for eg. 4- Quadcopter 6- Hexacopter 8- Octacopter etc.) has a certain set of design requirements after reviewing the crucial literature with reference to the research at hand, it has been found that selecting components and their mechanical feasibility, stability and need shall be fulfilled. The general procedure to design a drone follows the following steps:

1. Understanding and deciding the payload requirements.
2. Selecting a proper propulsion system to carry the payload and performing intended tasks.
3. Selecting the required power source and necessary electronics.
4. Selecting the support architecture for the payload, propulsion system and assembly weight.
5. Testing feasibility of design under mechanical aspects.
6. Deciding control parameters
7. Performing test runs and carrying out the tuning.

As a part of this dissertation it has been decided to focus on the crucial mechanical aspects of drone design. For the particular design assignment, the system is modelled in the suitable CAD system (CATIA V5). The mechanical components are analyzed for structural and mechanical stability using the FEA and CFD tool (ANSYS 19.2). The requirements for the flight of drone are analyzed and suitable parts are selected for the stable flight.

2. LITERATURE SURVEY

Kuantama, E et al[1] This paper is based on modelling and analysis of quadcopter frame. Author uses Finite Element Analysis for the analysis of frame of size 560 mm. The material used plastic of plastic modulus 3000 N/mm2 which was subjected to the thrust of 5302 g per rotor. For the analysis single arm was selected the thrust was applied at the rotor end while the other end was subjected to fix support condition. The resultant maximum displacement was found to be 3.3 mm and it varies from 0.8 to 1.7 with the central part.

Sastra M. K. et al[2] The centre focus of these designs was to increase strength by increasing the critical cross-sectional area and increasing moment of inertia of base of the section to reduce induce stresses. The three designs having weights 146g ,170.89 g and 179.71 g were compared the static stress values obtained are 2.93 MPa, 2.60 MPa and 1.09 MPa respectively and the maximum deformation were 0.696 mm, 0.495 mm and 0.208 mm respectively. Only design 3 was found to be most optimum.

Anudeep M et al **[3]** In this paper author deals with design of quadcopter and has done static analysis n frame to tolerate payload generated. In this paper author conclude top plate doesn't have more stress hence it is required to design base plate carefully say that it can sustain the loading condition.

Parth N. Patel et al[4] This paper deals with design of quadcopter for aerial surveillance. Aluminium 6061-T6 material was used to design the quadcopter. An innovative design is proposed where two arms of quadcopter can be folded after removing the propeller. The factor of safety of 10 with the design stress of 27.579 MPa were obtained under the given conditions.

Sai Mallikarjun Parandha, Zheng Li 2018 [5] This research mainly focused on 3D printing of X shaped frame for quadcopter. Author performed three types of analysis on X frame i.e. static structural, impact analysis and model analysis. The design was made in following manner: a 3D print quadcopter drone with safety factor of 2.5 and the designed was found safe. One of the main features of this frame is it can be upgraded by attaching 3D print 3-ais gimbal, thermal imaging sensors and gas sensors. This 3D printed drone can be customized and used in any environment by using different printed accessories.

Pulkit Sharma et al (2018) [6] In this paper author discusses about drone's landing capability, structural integrity and stress is studied to make sure that structure doesn't get collapse. Multiple tools for various factor like thrust, rpm and forward stress is developed. This model is used to understand flight plan of the drone with gravity considerations in non-linear analysis. The Author conclude that development of MATLAB required for thrust rpm forward speed plot , simplifies the calculation of thrust flight speed as well as it removes test and measures the thrust for propellers, decreases effort and increases precision. Non-linear analysis of drone frame for integrity, landing stability which help in real time insight about the drone frame. Conceptual design of drone helps to eliminate presence of unnecessary components in model, reducing the overall weight of structure. Hence it indicates robustness of frame and amount of payload that can carry without any failure.

Vijayanandh Raja[7] The author advocates design of hexacopter for forest monitoring with the payload of 1 kg and encompassing dimensions of 500 mm x 500 mm. The hexacopter is modelled in CATIA while the image processing is done using the MATLAB. According to the author, rate of climb and ground speed comparison between the hexacopter and quadcopter provides the basis that shows the hexacopter is better than that of quadcopter.

3. COMPONENT SELECTION

3.1 Payload:

As per the required monitoring operation a camera motion system along with the onboard optimum resolution camera is to be selected. The selected system for carrying out the following task includes the GoPro Hero 3+ (653g) and Zenmuse H3-3D 3-axis Gimbal system (190g). (look Annexure I for component specification.)

3.2 Propulsion System:

3.3 Power source and electronics:

A power source selection is a major part of designing the drone. A general power source for a multirotor drone is a LiPo battery which is the appropriate selection based on several factors, the most important one is the Battery capacity, Weight, Discharge rate (c), flight time and max continuous current drawn.

Max continuous current draw (A)= Battery capacity (Ah) x Discharge rate (c)

The flight time varies with the flight maneuvers but an estimate can be made based on the battery capacity.

The flight controller, being the brain/control unit of the drone receives command via receiver and provides appropriate control instructions to the electronic speed controller which in turn operates the motor by controlling its speed. The rating of ESCs are usually decide by the current drawn by the motor. The flight controller selection is rather independent of components used but it is the application specific as it controls the gimbal and receives feedback from the sensors. The flight controller handles the complex calculations and hence FC with F7 micro controller units are rather preferred because of their speed and memory. The flight controller comes with the supporting sensors, the important ones are Gyros and GPS. The Gyro Sensor also known as the inertia measurement unit of drone assembly controls the movement and orientation of drone and the GPS sensor collects the information of Global location to maintain its position.

3.4 Support Architecture or Frame:

The support structure of multirotor drone commonly referred to as Frame is selected based upon two critical requirements 1. The strength to withstand the assembly load 2. The propellers can be operated without interference. The major influence of aerodynamic loads is also a factor that influences the required frame selection. The frame should be kept as small as possible in order to maintain the weight constraints. It is also to be noted that the small frame shall also not fail under the loading of thrust and weight. The general material of construction of the drone frame is carbon fiber-based polymers which provides greater strength with respect to the density or weight of the overall frame. The frame dimensions are designated by the end to end distance of the opposite motor mounts on the respective arms.

3.5 Design Drone and Analysis Frame:

3.5.1 Component Selection:

The thrust requirement calculation is iterated for the optimum results. Adopting the selected procedure, the weight of selected components is calculated from the specification. (Refer: Appendix I).

Thrust Requirement= (Selected Ratio) x (No. of Motors) x (Motor Thrust Required) … (1)

Motor Thrust Required= (Weight of Assembly + Weight of Payload) / (No. of Motors) … (2)

Weight of Assembly= (Weight of Frame + Weight of Battery + Weight of Motor + Weight of Propeller + Weight of Required Electronics) … (3)

The Thrust to Weight ratio for this assembly for better control is selected as 3:1.

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Weight of Payload = Weight of Camera + Weight of Gimbal
=72.6+190g = 325g

After iterating for required thrust the following components were selected

Table 3.5.1 Component Selection

Component	No. of Components	Aggregate Weight (in grams)
DJI F450 Frame	4 arms + 2 Plates	282
T-Motor AT2814 900KV	4	432
Propellers	4	91.84
ESC ZTW (50A)	4	108
4S LiPo Battery	1	498
APM 2.8 Flight Controller	1	82
Electronics Components. Sensors and Wires	-	245
	Total Weight	1740

3.5.2 CAD model and Properties:

The CAD model is created in CATIA V5. For the analysis, the model is simplified to avoid meshing errors.

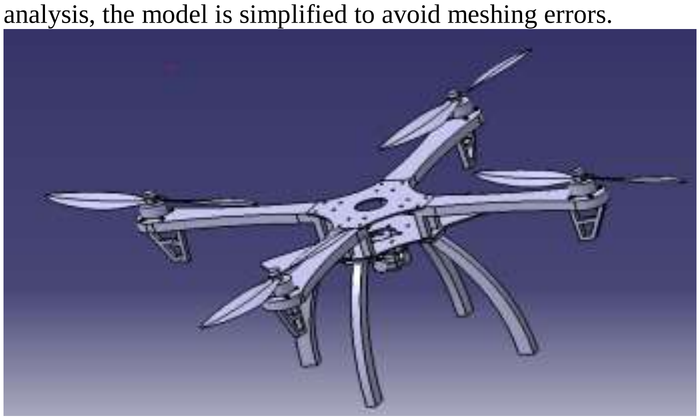

Fig.3.5.1 Simplified Model

3.6 CAD Model Properties

Table 3.6.1 Geometric Properties

Coordinates for Centre of Gravity in mm	
Gx	0
Gy	0
Gz	-23.1mm

Inertia Matrix: (Kg/m^2)			
IoxG	0.013	IxyG	-1.029E-4
IoyG	0.013	IxzG	3.049E-6
IozG	0.022	IyzG	-1.197E-6

3.7 The Thrust Calculations and Analysis:

After adding the weight of all the parts, it has been found that the resultant weight adds up to 1495 grams and the miscellaneous parts weights about 225 grams and solder adds up about 20 grams. The total adds up to 1740 grams i.e., 17.052 N.

The selected configuration for quadcopter will require to generate about 435 grams of thrust per motor to reach the operational speed (the speed at which drone is about to be lifted). In general, it has been selected for the survey operation a thrust to weight ratio of 3:1 which will constitute the thrust generated by each motor to 435*3= 1305 grams which is the substantial amount of thrust generated by selected motor. While the 435 grams of the total will generate stresses and the rest will contribute to generating the acceleration. Therefore, selecting the input value for structural analysis as 435 gram/motor i.e., 4.26735 N per motor and the weight acting through the center of gravity will be 1645 grams or 17.052 N.

Table 3.7.1 Material Properties

Sr. No.	Name of material	Ultrahigh Modulus Graphite/Epoxy UD Composite
1	Young's modulus (E)	290 GPa
2	Poisson's ratio (μ)	0.25
3	Density (ρ)	1700 Kg/ cubic meters

Fig 3.7.1 Equivalent Stress

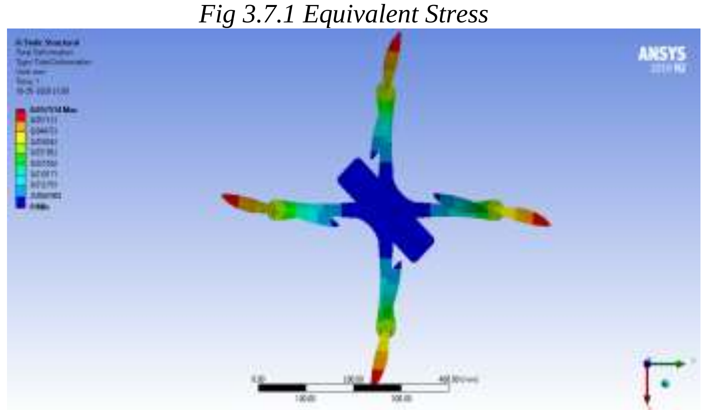

Fig 3.7.2 Total Deformation

4. RESULT

The frame analysis shows that the maximum stress (14.809 MPa) occurs along the top and bottom plate while the selected thickness is well within the safe value (bending strength=80-120 MPa and Compressive Strength= 150-250MPa) i.e., the design is safe. From the above analysis and numerical value, it is very clear that the material selected for this purpose the design is safe for given applied load/ thrust condition.

5. CONCLUSION

The stresses produced in the frame are in the safe limit rather a factor of safety of 6.33 is there for the lower limit. The design is safe under the loading conditions. Th
Use of appropriate motor and gimbal in the assembly obtained after the iteration can provide the required thrust as at 40% throttle thrust of about 744grams can be obtained which is significantly more when compared to the least thrust (435grams) required for the drone. While at 100% throttle of 2216 grams can be obtained which can improve manoeuvrings capabilities of drone. The PID controls can be established based on control equations for which the input parameters can be found in the CAD model.

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APPENDIX – I

Bill of Material

T-Motor AT 2814 900KV

Weight	108g
Power	650W/ 45A
Dimensions	Φ35.2 x 54.5 mm

Throttle (%)	RPM	Torque (N*m)	Thrust (g)	Efficiency (g/W)
40	6028	0.118	744	7.17
45	6411	0.134	847	6.84
50	6750	0.150	946	6.55
55	7078	0.165	1037	6.28
60	7407	0.185	1154	6.04
65	7773	0.210	1305	5.77
70	8171	0.234	1456	5.51
75	8565	0.260	1598	5.27
80	8948	0.291	1781	5.06
90	9729	0.348	2099	4.56
100	9927	0.370	2216	4.40

Propeller selected 11x 5.5

Dimensions	Φ 11” x 5.5
Weight	22.96 g

DJI F450 Frame

Diagonal Wheelbase	450mm
Weight	282g

Camera Go Pro Hero 3

Weight	72.6g
Max Resolution	12 MP
Dimensions	3 x 5.8 x 4.1 cm

ESC ZTW 50A

Continuous Current	50A
Burst Current	60A
Weight	27g
Size	56 x 30 x 14 mm

ZENMUSE H3-3D 3 AXIS GIMBAL

General and Peripheral:3- Axis, High Precision brushless servo control, Aluminum alloy Body.	
Mechanical and Electrical Characteristics	
Working Current	Static 400mA @ 12V Dynamic 600mA @ 12V
Gimbal Input Power	3S-6S (12V-26V)
Gimbal Weight	168g
Gimbal Dimensions	97x95x73 all in mm
GCU weight	22g
GCU dimensions	42x32x9.3 all in mm
Angular Vibration Range	Pitch/Roll: ±0.02˚, Yaw: ±0.03˚
Maximum Controlled Rotation Speed	Tilt axis: ±130˚/s
Controlled Rotation Range	Tilt axis control -130 ~ +45˚

APM 2.8 Flight Controller

Weight	82g
Size	85 x 45 x 15mm

Battery 5000 mAh 4S Li-Po

Capacity	5000mAh
Nominal Voltage	14.8 V
Configuration	4S1P
Discharge Rate	60C
Max Burst Discharge Rate	120C
Net Weight	498g
Dimensions	144 x 51 x 39 mm