Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 11, Special Issue 12, 2023
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Research JoPC

Optimal Design and Fabrication of Drone for Agricultural Purpose

Sasidhar Gurugubelli[1,*], Kaveri G.[2], K. Vamsi Krishna[3], G. Manideep[4], G. Ganesh[5], M. Rajkumar[6]

Abstract

Due to their reliable technology and simple operation, drones have found widespread use in many fields. This study aims to plan, investigate, and build a quadcopter for use in farming. This drone is implanted for pesticide spray in the farms. An innovative quadcopter design that is easily removable and transportable is used in this study. The entire structure is developed in Iron CAD, and the viability of the new design is verified using stress analysis in ANSYS. Using the ANSYS analysis tool, the finite element analysis for the quadcopter body was conducted under extreme ambient conditions, and the stress distribution of the body was presented. Under the same load conditions, deflection and stress of the body are found at 6.17 mm and 8.11 MPa, respectively. PLA is used as the appropriate material for manufacture. A flight controller module with Arduino and MPU6050In is used to streamline and reduce the cost of the drone. Also, a GPS module was used to stand and deliver control at one stop.

Keywords: Quad-Copter, ANSYS, Arduino, MPU6050, Agriculture

INTRODUCTION

Drones have undergone quite a remarkable evolution throughout time. Drones were primarily developed for military use but are currently utilized in various ways. Due to their reliable technology and simple operation, drones have found widespread use in many fields. This study aims to plan, investigate, and build a quadcopter for use in farming. This drone is implanted for pesticide spray in the farms. An innovative quadcopter design that is easily removable and transportable is used in this study. The entire structure is developed in Iron CAD, and the viability of the new design is verified using stress analysis in ANSYS; PLA is used as the appropriate material for manufacture. A flight controller module with Arduino and MPU6050In is used to streamline and reduce the cost of the drone. Also, a GPS module was used to stand and deliver control at one stop.

***Author for Correspondence**
Sasidhar Gurugubelli

[1]Assistant Professor, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India
[2]Graduate Student, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India
[3]Graduate Student, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India
[4]Graduate Student, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India
[5]Graduate Student, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India
[6]Graduate Student, Mechanical Department, GMR Institute of Technology, Rajam, Andhra Pradesh, India

Received Date: October 30, 2023
Accepted Date: November 23, 2023
Published Date: March 29, 2024

Citation: Sasidhar Gurugubelli, Kaveri G., K. Vamsi Krishna, G. Manideep, G. Ganesh, M. Rajkumar. Optimal Design and Fabrication of Drone for Agricultural Purpose. Journal of Polymer & Composites. 2023; 11(Special Issue 12): S81–S92.

Industries are becoming more and more well-liked among amateurs. When the Austrians assaulted Venice with explosive-loaded balloons in the middle of the 19th century, uncrewed aerial vehicles (UAVs) were first invented. However, during World Wars I and II, the development of remote-controlled aircraft significantly improved drone technology. Drones came to widespread notice during the Cold War because of surveillance drones deployed for reconnaissance. As technology advanced and costs fell, businesses began to adopt drones: agricultural surveys, filmmaking, and aerial photography.

Faraz Ahmad et al. [1] study involves designing the propellers in Creo 2.0 software and analyzing them using Ansys 16.2 for their vibration frequencies. The authors then describe the 3D

CAD model and material properties used in the study. Pulkit Sharm et al. [2] designed a paper drone that can operate in land, water, and air environments. The weight-carrying capacity of the drone is evaluated through simulations where the weight of the components is gradually increased until failure occurs. UM, Rao Mogili et al. [3] studied integration, which offers accurate site-specific applications for large crop fields. Heavy lift UAVs are required for spraying large areas, and the spraying system's efficiency can be improved by using PWM controllers. Tadeusz Kosmal, Kieran Beaumon, et al. [4] studied hybrid additive manufacturing (AM) robotic work cells capable of autonomously fabricating complete mechatronic systems, focusing on drone fabrication.

Sahin Yildirim et al. [5] discussed the design, modeling, and control of a universal drone system that can be reconfigured according to different usage purposes by changing the number of rotors and arm lengths. Satoshi Satoh et al. [6] focus on a quadcopter's position and attitude control in the presence of stochastic disturbances. To solve this problem, the paper proposes a continuous-time stochastic differential dynamic programming (DDP) method. Arun Pratap Singh [7] introduces a strategy for designing and manufacturing a quadcopter with a pesticide spraying tank for horticultural applications. Zhang Haidong et al. [8] discuss the UAV-LARS (unmanned aerial vehicle low-altitude remote sensing) technology that uses drones to collect data about the agricultural field.

Sairoel Amertet1 et al. [9] discuss the concept of connected to Mechatronics systems, which have the potential to increase agricultural production, save water, and provide financial analysis findings to farmers based on extensive data analysis. Ahmed Eltaye et al. [10] studied a dynamic model and PID trajectory tracking control design for a quadcopter UAV. Yallappa et al. [11] discuss developing and evaluating a drone-mounted sprayer for pesticide applications to crops. Dan Andritoiu et al., [12] The authors' solution is to create an automated decision and monitoring system through the use of customized if the implementation of monitoring systems using aerial drones equipped with specialized near-infrared (NIR) inspection systems is already one of the specific themes of the current technological revolution.

Rasel Hossain et al. [13] discuss that the frame, propeller, engine, power system, electronic control, and communication systems are the drone's most crucial structural elements, which are discussed in detail before covering the uses of drones. NGUYEN XUAN-MUNG et al. [14] concern about obtaining completely autonomous quadcopter flying has become a crucial problem investigated in numerous studies due to quadcopter uncrewed aerial vehicles' growing popularity in real-world applications. Sagar Nvss et al. [15] discuss that Commercial UAV designs feature multiple parts and fastening components, making assembly labor- and time-intensive. Ubaid your Rehman et al. [16] concerns about the frame being re-engineered as a monocoque structure with the desired weight-saving effects. This study focuses on compiling such cutting-edge mechatronic technology in the agriculture sector and analyzing the merits and limitations of the contemporary approach. Shaw KK et al. [17] discuss that the quadcopter drone can return to the starting place after delivering a requested parcel. Future studies on the use of quadcopters for package delivery are made possible by this method's encouraging results.

This work aims to build an optimized design of a quadcopter that should carry a total weight of 2.5 kg, including body weight. The parts selection should be done in an economical way and as per the load considerations.

MATERIALS AND METHODOLOGY

This paper focuses on three crucial aspects of quadcopter advancement. Each of these components was crucial to the overall success of the system in this attempt. The frame, additional components, and flight controller are the three components. Figure 1 is a block diagram depicting the relationships between the components presented there.

Analytical Design of the wing

Considering the designed wing as a cantilever beam

Length of beam (L) = 160 mm

Width of beam (b) = 34 mm

Height of beam (d) = 10 mm

Point load (w) = 6 N

We know that, to find stress in beam

$\sigma/y = M/I$

$\sigma = M \times y/I$

$= 160 * 6$

$M = 960$ N-mm

where, σ = stress

M = bending moment in beam

I = moment of inertia

Y = distance to point from neutral axis

To calculate bending moment (M) = w × L

Moment of inertia (I) = bd3/12 (for rectangular section)

b = 34, d=10

= 34*(10)3/12

= 34*1000/12

= 34000/12 = 2833.34 mm^4

Stress (σ) = M × y/I

= (960*5)/2833.34 (where, y =d/2 = 10/2 = 5)

= 4800/2833.34

σ = 1.694 N/mm^2 = 1.694 Mpa

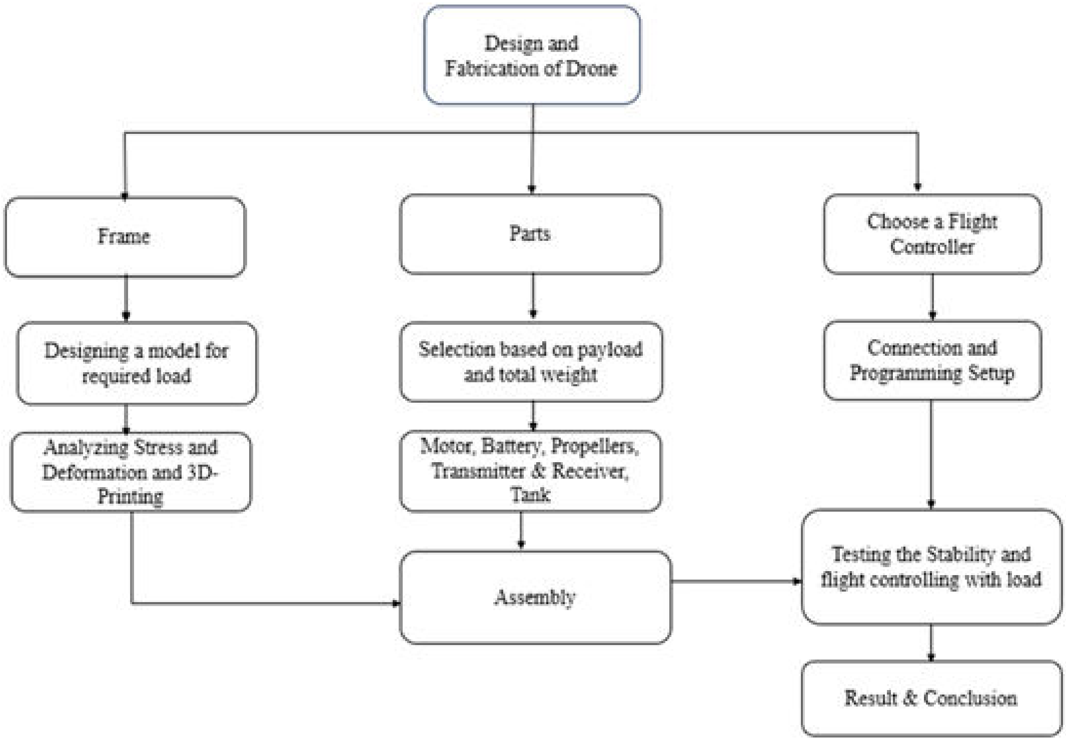

Figure 1. Methodology of the work.

Table 1. Propeller design parameters.

Diameter	9”	10”	11”
Pitch	4.7”	4.5”	5”
Mass	780 g	880 g	960 g

Table 2. Motor design parameters.

Kv	Model	Max amps	Thrust (max)	Price (Rs)
1000kv	A2212	19.2 A	720 gm	600–700
920kv	dJI2212	14 A	700 gm	700–800
935 kv	MT2213	12 A	900 gm	1150–1200
750 kv	5010	15 A	1000 gm	1600–1800

Parts Selection

Propeller & Motor

On each of the brushless engines there are mounted a propeller. The 4 propellers are really not indistinguishable. Three set of propeller design is considered which is sown in the Table 1.

10” inch propeller is used for manufacture of drone for our design requirements.

Smaller or medium-sized propellers are better for high-RPM engines, whereas larger propellers provide greater thrust each revolution. For our requirement and the usage of propeller the 935 kv motor is used. Maximum current used by the motor is 12A. Max rpm of the motor is 11220 rpm which is shown in the Table 2.

Electric Speed Controller

Choosing an ESC is up to the maximum amps of motor. The 12A motor is used. It is suitable to use an ESC is more than 12A. So, 30A ESC is used because, it will be safe as double as the amps of motor.

Battery

Lithium polymer is used due to the light weight. 3s Lipo battery is used it gives maximum voltage of 4.2 v when it fully charged, it drops slowly to 3.7 v for most of the battery life.

3S = cell count of the battery (3 cells)

30C = maximum continuous discharge rate

11.1 V = Volatge of the battery

2200 mah = 2.2 ah = battery capacity

1 cell = 4.2 volts max

Efficient voltage drawn up to 3.3 v per cell

Per cell = (3.3/4.2)100

= 78% efficiency is perfect

A = 2.2 × 0.78 = 1.7 Ah (effective).

Flight time calculation

The flight time and weight of the quadcopter are the primary factors that determine the total cost, total time required to complete the process, and total efficacy of the framework. Therefore, it is crucial to work on these aspects to make the drone framework run quickly and comfortably.

Flight time = Battery Capacity (ah)/max Current drawn (A) x 60

By considering effective Battery Capacity of 1.7 Ah, Calculating the flight time while taking various weights into account. First, perform the calculations with the weights listed below using the 3s (3-cell) 2.2 Ah battery with voltage of 11.1 volts and 30 c discharge rate.

Flight time calculation for four different weights is discussed below.

- Consider the total weight of drone as 1600g m. The total weight is distributed to four motors equally. Each motor lifts 400 gm. Whereas, to attain the 400 gm of thrust the current drawn is 5 amp. Then to lift the total weight of 1600 gm will be four times the current drawn of the single motor i.e., 20 amp.

Flight time=1.7/20 × 60 = 5.1 minutes.

- Consider the total weight of drone as 2000 gm. The total weight is distributed to four motors equally. Each motor lifts 500 gm. Whereas, to attain the 500 gm of thrust the current drawn is 6.5 amp. Then to lift the total weight of 2000 gm will be four times the current drawn of the single motor i.e., 26 amp.

Flight time=1.7/20 × 60 = 3.92 minutes.

- Consider the total weight of drone as 2400g m. The total weight is distributed to four motors equally. Each motor lifts 600gm. Whereas, to attain the 600 gm of thrust the current drawn is 8amp. Then to lift the total weight of 3400 gm will be four times the current drawn of the single motor i.e., 32 amp.

Flight time=1.7/20 × 60 = 3.18 minutes.

- Consider the total weight of drone as 3200 gm. The total weight is distributed to four motors equally. Each motor lifts 800 gm. Whereas, to attain the 800 gm of thrust the current drawn is 12amp. Then to lift the total weight of 1600gm will be four times the current drawn of the single motor i.e., 48amp.

Flight time=1.7/20 × 60 = 2.12 minutes.

Again, perform the calculations with the weights listed below using the 3s (3-cell) 4.2 Ah battery with voltage of 11.1 volts and 35 c discharge rate.

Max current = 4.2×35 = 147A.

Maximum current attain for 35c battery is 147A

A = 4.2 ah at 100 % efficiency (MAX).

Per cell =0.78% = 3.2 Ah

This battery has a 4.2 Ah capacity as 100% efficiency. The effective rate of capacity to draw from a cell is 78% which means 3.2 Ah is the battery's effective capacity.

- Consider the total weight of drone as 1600 gm. The total weight is distributed to four motors equally. Each motor lifts 400 gm. Whereas, to attain the 400 gm of thrust the current drawn is 5 amp. Then to lift the total weight of 1600 gm will be four times the current drawn of the single motor i.e., 20 amp.

Flight time=1.7/20 × 60 = 9.6 minutes.

- Consider the total weight of drone as 2000 gm. The total weight is distributed to four motors equally. Each motor lifts 500 gm. Whereas, to attain the 500 gm of thrust the current drawn is 6.5 amp. Then to lift the total weight of 2000 gm will be four times the current drawn of the single motor i.e., 26 amp.

Flight time=1.7/20 × 60 = 7.38 minutes.

- Consider the total weight of drone as 2400 gm. The total weight is distributed to four motors equally. Each motor lifts 600 gm. Whereas, to attain the 600 gm of thrust the current drawn is 8 amp. Then to lift the total weight of 3400 gm will be four times the current drawn of the single motor i.e., 32 amp.

Flight time=1.7/20 × 60 = 6 minutes.

- Consider the total weight of drone as 3200gm. The total weight is distributed to four motors equally. Each motor lifts 800 gm. Whereas, to attain the 800 gm of thrust the current drawn is 12 amp. Then to lift the total weight of 1600 gm will be four times the current drawn of the single motor i.e., 48 amp.

Flight time=1.7/20 × 60 = 4 minutes.

Take into account that the drone weighs between 1300 gm–1400 gm (based on battery used) and taking 1000 gm as pay load capacity. The drone can lift a total weight of 2400 g.

Weight of the drone = (1300 to 1400) g.

Payload to carry = 1000 g (900 ml).

Total weight to lift = 1400 + 1000.

= 2400 g

In order for the quadcopter to function optimally, the following estimates of its fligt time and weight parameters are necessary.

- Total weight to lift = 2400 grams
- Battery Capacity = 2.20 Ah
- Time of spraying = 4 minutes

CAD BASED ANALYSIS

CAD Design

Iron CAD software was used to design the drone after considering its intended use in the field. The frame's bottom and top are individual pieces that will be joined together with screws. Drone motors are held firmly in place by motor holders that were also custom-made. The central hub, spars, and wings are designed individually and assembled, shown in Figures 2, 3, and 4, respectively.

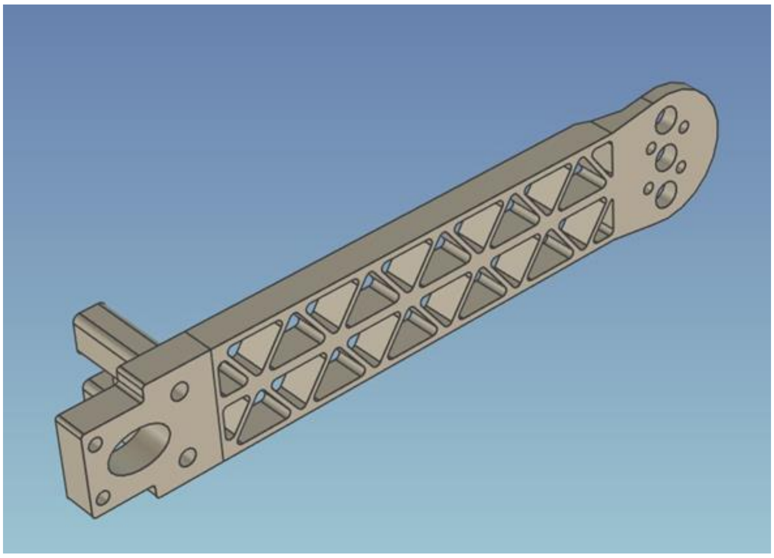

Figure 2. Design of drone wing in Iron cad.

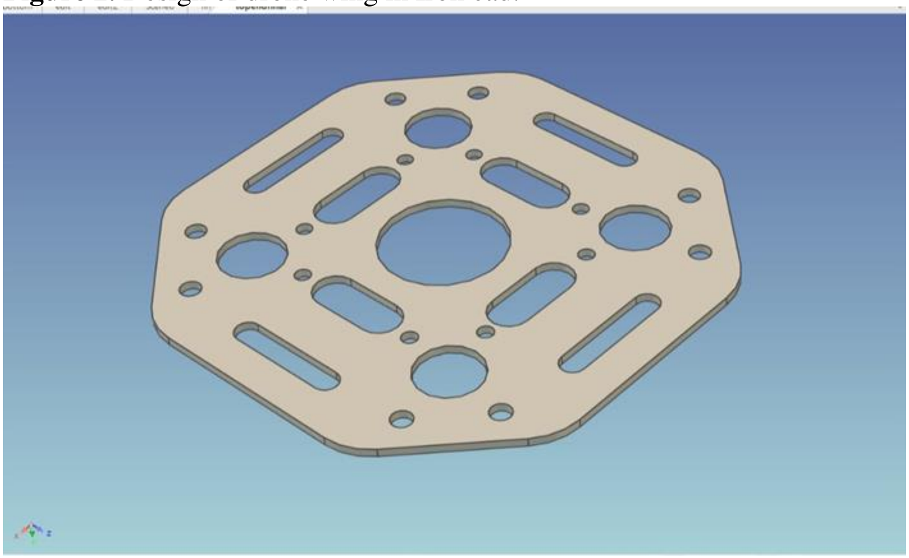

Figure 3. Design of drone frame in Iron cad.

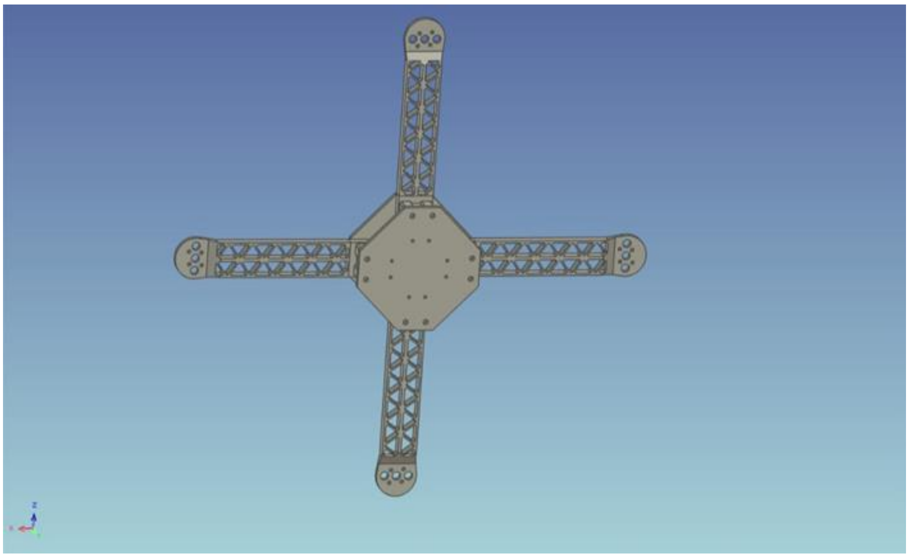

Figure 4. Assembly of drone in Iron cad.

Structural Analysis

Structure analysis of a drone involves analyzing the behavior of the drone structure under different loads and conditions. This includes determining the drone frame's stresses, deformations, and safety factors when subjected to external loads such as forces. The analysis can be done using mathematical models, computer simulations, or physical testing. In the context of the quadcopter design, a Static structural study was performed on the complete drone frame using ANSYS software to validate its stability and ensure that it can withstand the pressures experienced in the air.

The Structural analysis of the drone was done by considering the arm and body as one part. The meshing and structural research was conducted for finer results and deformation outcomes at loading conditions.

Meshing

The meshing of the drone body was done in ANSYS workbench with polygon type meshing which gives better results for this structure. Further the mesh size is 3.5e–0.3m as shown in Figure 5. which produces finer results in terms of static load analysis.

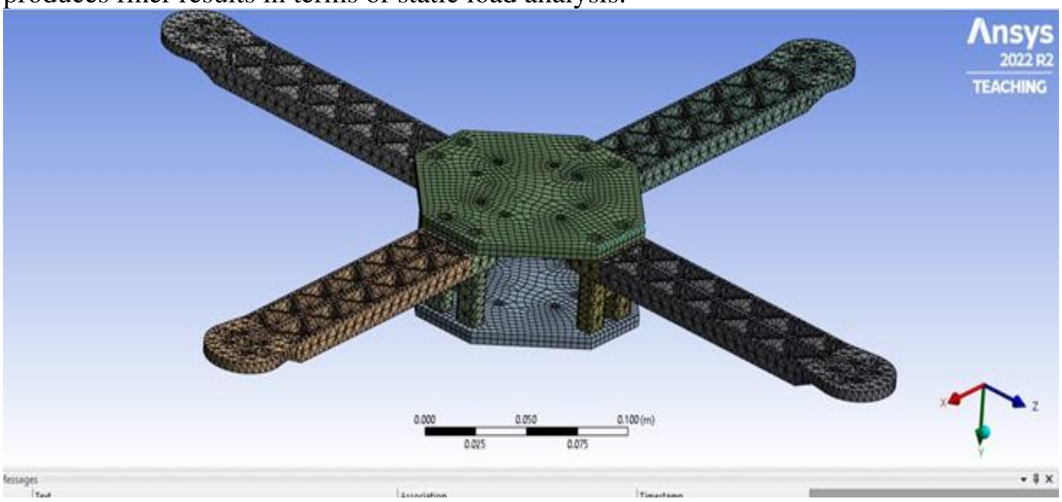

Figure 5. Meshing of total body in ANSYS.

Journal of Polymer & Composites
Volume 11, Special Issue 12
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

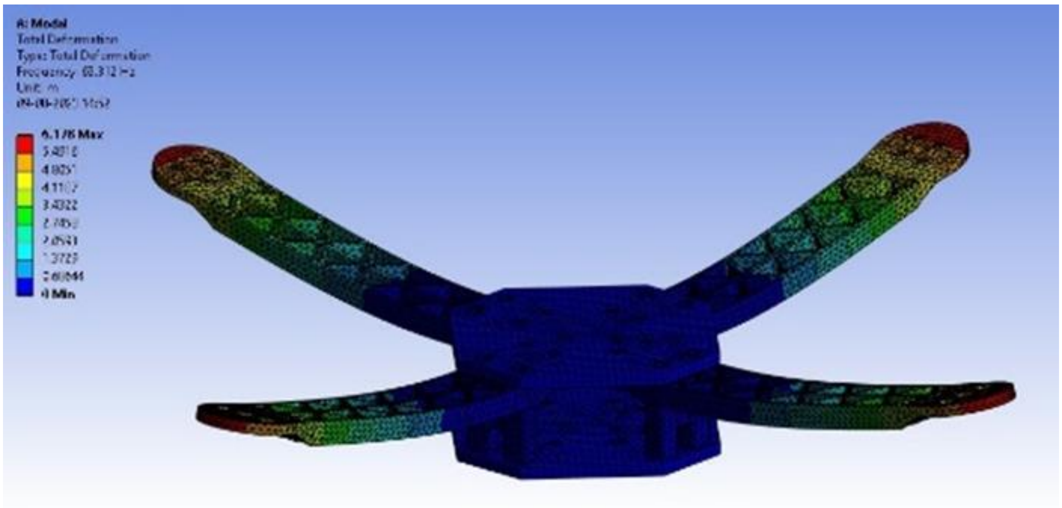

Figure 6. Total deformation of PLA material.

Loading and Boundary Conditions

Since the lift is solely provided by the motors, the center HUB of the body was made as fixed support, and a load of 6N was applied on each motor base with a Factor of Safety of 6.75. Per the motor specifications and performance, each motor is set to give a maximum thrust of 900 gm. The structural deformation of the body was studied under these loading conditions.

RESULTS AND DISCUSSION

We calculated the total deformation for the loads mentioned earlier and materials in ambient air using the ANSYS structural analysis tool. Conditions leading to deformation are displayed below.

Total Deformation

Once the Iron Cad file has been converted to the.sat file format to import into the Ansys workbench, the total body was selected and meshing constraints as 3.5e-0.3m with face size mesh after choosing modal analysis. Additionally, the wings can deform by attaching the bottom end as a fixed support.

The total deformation value of PLA (Polylactic Acid) is 6.178 mm, as illustrated in Figure 6, and it depicts the maximum displacement that occurred in the center of the wing frame, which was determined to be between 2.7 and 0.6 mm. The material used is PLA (Polylactic Acid) with a Youngs modulus of 3500(N/mm^2). In this case, the Drone has a good rigidity with designed wing frame size. As a whole, the frame weighs 218 (grams).

Maximum Principal Stress (Mpa)

After importing the geometry to the Ansys workbench, the total body was selected, and meshing constraints were 3.5e-0.3m with face size mesh after choosing structural analysis. Additionally, the force is applied on each wing of 6N upwards as the motors' thrust acts in that direction, and the bottom end and top end are set to be fixed. Maximum and minimum values of the everyday stress can be calculated. Significant primary pressure refers to the most critical deal of daily stress, whereas minor principal focus refers to the most negligible value of everyday stress. Figure 7 displays the maximum paramount pressure of 8.1159 MPa determined for the drone under identical loading conditions.

Fabrication of Drone in 3d Printer

The ultimate Cura software is used to slice the 3D object designed in Iron Cad software by choosing the infill percentage and layer height, followed by material selection, which generates the Gcodes to process in a 3D printer (X-Max 3D). We selected the PLA material based on results obtained from Ansys software. Figure 8 shows the printing of the wing of the drone. The Infill of the product is 100%, the layer height is 0.15 mm, and the zig-zag pattern.

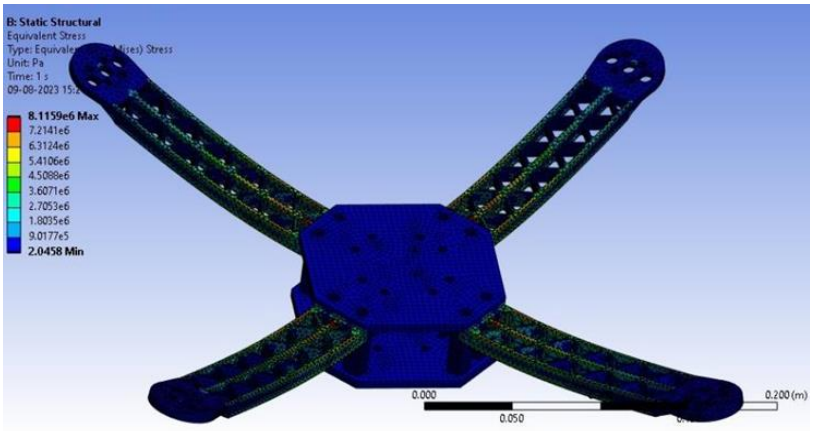

Figure 7. Equivalent stress of PLA material.

Figure 8. 3d printing of the drone wing.

It takes around 8 hrs for printing the one wing. Figure 9 shows the final product of fabricated quadcopter wing. Like this there are 4 wings for a Quadcopter. The bed temperature for 3d printer for using PLA material is 60°c and the filament temperature is 212°c.

The drone frame is also made by using 3d printing for that infill is 100% and the layer height is 0.15 mm and the thickness is 2 mm it takes around 5 hrs to print which is shown in Figure 10.

Assembly and flight testing of the quadcopter drone's 3D-printed arms attached to the drone's body. An electronic speed controller (ESC) is connected to a Brushless DC motor. The ESC is positioned in the center of the arms, while the motors are placed on the edges. The power is distributed to each component using a power distribution board. The drone's flying controller is constructed using an Arduino Uno (R3) as the microcontroller and an MPU6050 as the gyroscope sensor. It is connected to the receiver and ESC. Figures 11 12 depicts an assembled drone in top and isometric views. Flight testing is done on the drone. A weight of 2.5 kg has been lifted using the designed drone.

Journal of Polymer & Composites
Volume 11, Special Issue 12
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

Figure 9. Quadcopter wing after printing.

Figure 10. 3D printing of Frame.

Figure 11. Top view of the drone.

Figure 12. Isometric view of the drone.

CONCLUSION

It has been concluded that the designed frame is optimal according to the load requirement as well as part selections discussed above in the paper, and Arduino Uno (R3) with the addition of the MPU6050 module has been selected as a flight controller and the code used in the flight controller is open-source code. It is calibrated according to our required stability as needed.

1. The quadcopter drone can fly quickly to its destination due to the use of light materials in the device's construction.
2. This paper thoroughly details the design and construction of a quadcopter.
3. Components like wings and frames of drones are produced via an additive manufacturing process (3D printing).
4. Iron cad is used to design the drone frame and motor support wings.
5. Ansys software is used for analysis; as a result, the equivalent stress value obtained is 8.1159 MPa, which is safe. At the same time, the maximum stress value of PLA material is 37 MPa, which is a safe design.
6. Arduino Uno (R3) as the microcontroller and an MPU6050 as the gyroscope sensor are used as flight controllers.

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

7. Using the selected battery per our designed consideration, the flight time is 4 minutes.
8. I have successfully assembled the drone by attaching sprinklers to spray the liquids. Suitable for use in small crop areas.
9. Complete mechanization has been achieved for the above reason. Because of its novel layout, the product has improved safety, cost, efficiency, and utility for rural areas.

REFERENCES

1. Ahmad F, Kumar P, Patil PP. Analysis of a Pre-Stressed Quadcopter Propeller Using Finite Element Approach. Journal of Graphic Era University. 2021 Jun 9:105–20.
2. Sharma P. Conceptual design and non-linear analysis of triphibian drone. Procedia computer science. 2018 Jan 1;133:448–55.
3. Mogili UR, Deepak BB. Review on application of drone systems in precision agriculture. Procedia computer science. 2018 Jan 1;133:502–9.
4. Kosmal T, Beaumont K, Link E, Phillips D, Pulling C, Wotton H, Kudrna C, Kubalak J, Williams C. Hybrid additive robotic workcell for autonomous fabrication of mechatronic systems-A case study of drone fabrication. Additive Manufacturing Letters. 2022 Dec 1;3:100100.
5. Yıldırım Ş, Çabuk N, Bakırcıoğlu V. Design and trajectory control of universal drone system. Measurement. 2019 Dec 1;147:106834.
6. Satoh S, Saijo H, Yamada K. Optimal Position and Attitude Control of Quadcopter Using Stochastic Differential Dynamic Programming with Input Saturation Constraints. Journal of Robotics and Mechatronics. 2021 Apr 20;33(2):283–91.
7. Singh AP. QUADCOPTER FOR AN AGRICULTURAL APPLICATION, Vision & Quest, Vol. 8, No. 2, July-Dec. 2018 ISSN: 0975–8410.
8. Zhang H, Wang L, Tian T, Yin J. A review of unmanned aerial vehicle low-altitude remote sensing (UAV-LARS) use in agricultural monitoring in China. Remote Sensing. 2021 Mar 23;13(6):1221.
9. Gebresenbet G, Finecomess SA. Assessment of the Smart Mechatronics Application in Agricultural: A Review, (2023).
10. Eltayeb A, Rahmat MF, Basri MA, Shamsudin AU, Nawawi SW, Sahlan S, Zakaria Z. QUADCOPTER UAV DYNAMIC MODELING AND PID TRAJECTORY TRACKING CONTROL DESIGN.
11. Devi G, Sowmiya N, Yasoda K, Muthulakshmi K, Balasubramanian K. Review on application of drones for crop health monitoring and spraying pesticides and fertilizer. J. Crit. Rev. 2020;7(6):667–72.
12. Andritoiu D, Bazavan LC, Besnea FL, Roibu H, Bizdoaca NG. Agriculture autonomous monitoring and decisional mechatronic system. In 2018 19th International carpathian control Conference (ICCC) 2018 May 28 (pp. 241–246). IEEE.
13. Hossain R. A Short Review of the Drone Technology. International Journal of Mechatronics and Manufacturing Technology, https://www. researchgate. net/publication/362908663_A_Short_ Review_of_the_Drone_Technology, Viitattu. 2022;27:2023.
14. Xuan-Mung N, Hong SK, Nguyen NP, Le TL. Autonomous quadcopter precision landing onto a heaving platform: New method and experiment. IEEE Access. 2020 Sep 9;8:167192-202.
15. Nvss S, Esakki B, Yang LJ, Udayagiri C, Vepa KS. Design and development of unibody quadcopter structure using optimization and additive manufacturing techniques. Designs. 2022 Jan 22;6(1):8.
16. ur Rehman U, Iqbal T, Hussain S, Cheema MJ, Iqbal F, Basit A. Drone and Robotics Roadmap for Agriculture Crops in Pakistan: A Review. Environmental Sciences Proceedings. 2023 Feb 3;23(1):39.
17. Shaw KK, Vimalkumar R. Design and development of a drone for spraying pesticides, fertilizers and disinfectants. Engineering Research & Technology (IJERT). 2020 May

