Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.1, May : 2024

CONSTRUCTION AND DEVELOPMENT OF GENERAL-PURPOSE DRONE

Mr. AANCHAL DUBEY, Mr. ARPIT SAHARAN, Student, B.Tech. Mechanical Engineering (Evening), School of Mechanical Engineering, Lingaya's Vidyapeeth, Faridabad, Haryana
Guided by **DR. DK BHALLA-** Professor and LEET coordinator B. Tech, M. Tech., PhD, FIE in Lingaya's Vidyapeeth, Faridabad, Haryana

I. Abstract

The construction of a general-purpose drone involves the assembly of essential components designed to offer a balance between performance, versatility, and cost-effectiveness. Key elements include a lightweight, durable airframe, adaptable payload systems, user-friendly control mechanisms, and reliable power sources. The design process starts with defining the drone's primary functions, ensuring that it can accommodate a variety of sensors and equipment for different applications such as aerial photography, surveying, and basic cargo delivery.

During construction, a modular approach is often adopted, allowing for easy customization and upgrades. The drone's propulsion system is selected to provide sufficient lift and maneuverability while maintaining efficiency for reasonable flight times. Advanced electronics are integrated to support autonomous flight capabilities, GPS navigation, and real-time data transmission. Safety features, such as obstacle avoidance and fail-safe return-to-home functions, are also incorporated.

The final product is a multi-functional UAV that serves as a flexible platform suitable for both hobbyists and various industries, capable of performing a wide range of tasks with minimal adjustments. The general-purpose drone stands as a testament to the accessibility and adaptability of UAV technology in the modern era.

Keywords: Drone, delivery, mechatronics, propeller, SolidWorks

II. Introduction

General-purpose drones are versatile unmanned aerial vehicles designed for a broad range of applications across various industries. Unlike specialized drones tailored for specific tasks such as military surveillance or precision agriculture, general-purpose drones are adaptable and can be used for multiple functions including photography, videography, surveying, inspection, and recreational flying.

Key features of general-purpose drones include:

1. Modularity: They often have modular designs allowing for easy attachment and detachment of different payloads like cameras, sensors, or cargo carriers to suit various tasks.
2. User-Friendly Controls: These drones are typically equipped with user-friendly interfaces, making them accessible to both professionals and hobbyists. They often come with pre-programmed flight modes, automatic takeoff and landing, and GPS-guidance systems.
3. Durability and Portability: Built to withstand a range of environments, general-purpose drones are often lightweight and portable, with some models featuring foldable designs for easy transportation.
4. Affordability: Since they cater to a broader market, manufacturers aim to keep costs relatively low compared to specialized drones, making them more accessible to the general public and small businesses.
5. Flight Capabilities: They are designed with a balance of flight time, range, and speed to accommodate a variety of uses without focusing on any extreme performance characteristic.

General-purpose drones have become increasingly popular due to their flexibility and ease of use, making them a valuable tool for enthusiasts and professionals alike. They are often the entry point for individuals and organizations looking to explore the benefits of drone technology without committing to a high-cost, specialized UAV.

III. Background of the study.

1. CAD Design and Analyses

As a CAD designer I used SolidWorks, which is a 3-D modeling CAD and CAE software that runs primarily on Windows operating systems. It is used for mechatronics systems development from the start to the end. Initially, SolidWorks is used to plan, visualize ideation, model, assess feasibility, prototype, and manage projects. Then, it is used to design and build software, mechanical, and electrical elements.

This software can also perform different analyses on the product to check its behavior in the real world. Hence, it can be tested differently before the product is manufactured. To make it clearer, the product can go through three stages using this software.

2. Frame:

One of the most critical parts is the frame in every design. It needs to be formable, rigid (the material is selected carefully), and able to withstand the pressure and the seasonal weather like rain, wind, and so on so that the vehicle does not fail. Furthermore, it can be used as a mounting platform for all crucial components (mechanical, electrical, and propulsion).To prepare a design for my drone project, many designs were observed from different websites. However, the one chosen by me is a wooden drone frame from a website called Grab- Cad, and many modifications have been made according to the material, dimensions, and thickness needed. I chose this type of frame because I am planning to laser cut it. Once I am done with the project the newly developed design will be uploaded to the same website to make it available for interested members. The two figures below show the frame chosen in both the collapsed and exploded view [1].

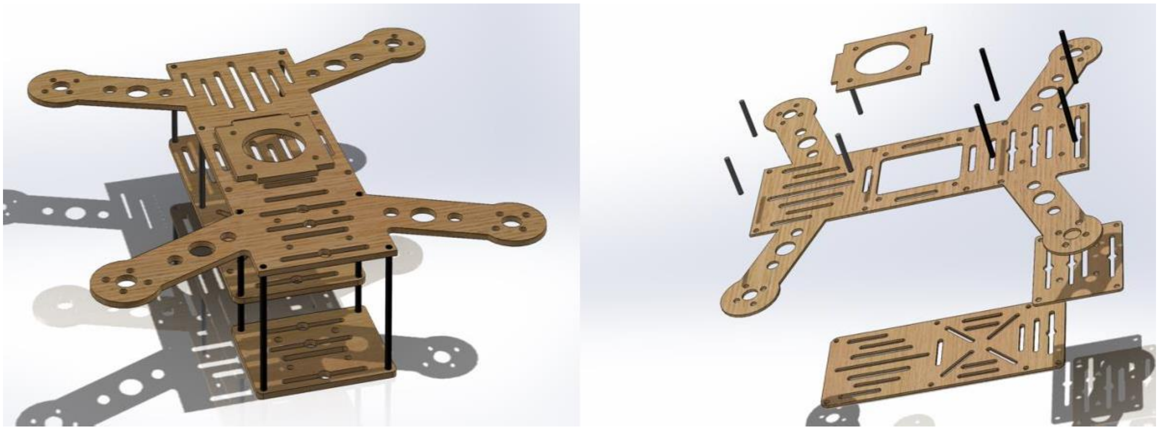


Figure 16: (a) The collapsed view of the drone. (b) The exploded view of the drone.

Before launching a product on the market, a prototype should be made. Nonetheless, in addition to the time and money to make a prototype, analyses and tests should be performed to assure its design effectiveness and physical capabilities. Nowadays, many manufacturers use CAE or CAD to either 3D print or laser cut a desired product.

Von Mises Stress: is used as a value to determine whether a given material is going to fracture or yield. The von mises yield criterion states if a material's von Mises stress under load is greater or equal the yield limit of the same material then the material will yield.

Displacement: shows how my model moves in the chosen direction, and if the deformation scale given is one then it is a real deformation; otherwise, it is not the case.

Strain: is a geometric response measure and the shape changes due to its applied forces. It is expressed as: $\varepsilon = \Delta l / l$.

The figures below show the drop test analysis results of each material:

a) Plywood.

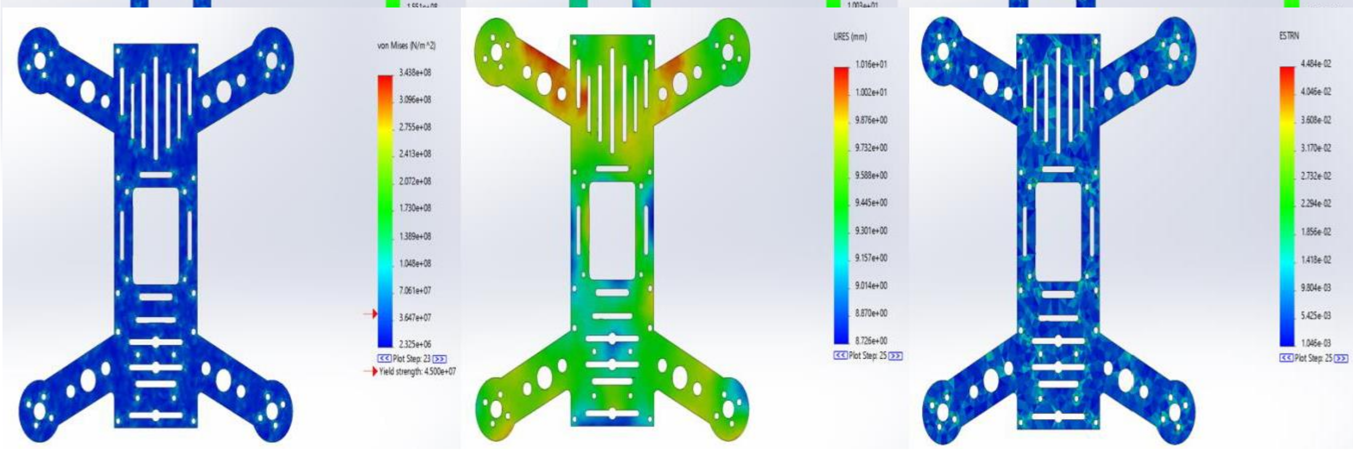
In figure 18 (a), it shows that the yield strength of the material is 15.6 MPa, and after the drone is dropped from a height of 100 meters the von Mises stress is around 16 MPa, which means that von Mises stress > The yield strength then the material will yield.

In figure 18 (b), it shows that the minimum displacement is 9.634 mm, and the maximum is 10.43 mm. The red area it shows where it is going to deform. However, from the colors, we can see that the displacement of the drone at a height of 100 m is in between. From figure 18 (c), we can see that the minimum and maximum strains are 3.829×10^{-4} and 2.623×10^{-2}.

Figure 18: (a) Von Mises Stress, (b) Displacement, and (c) Strain in Plywood.

b) Acrylic (Plexiglass):

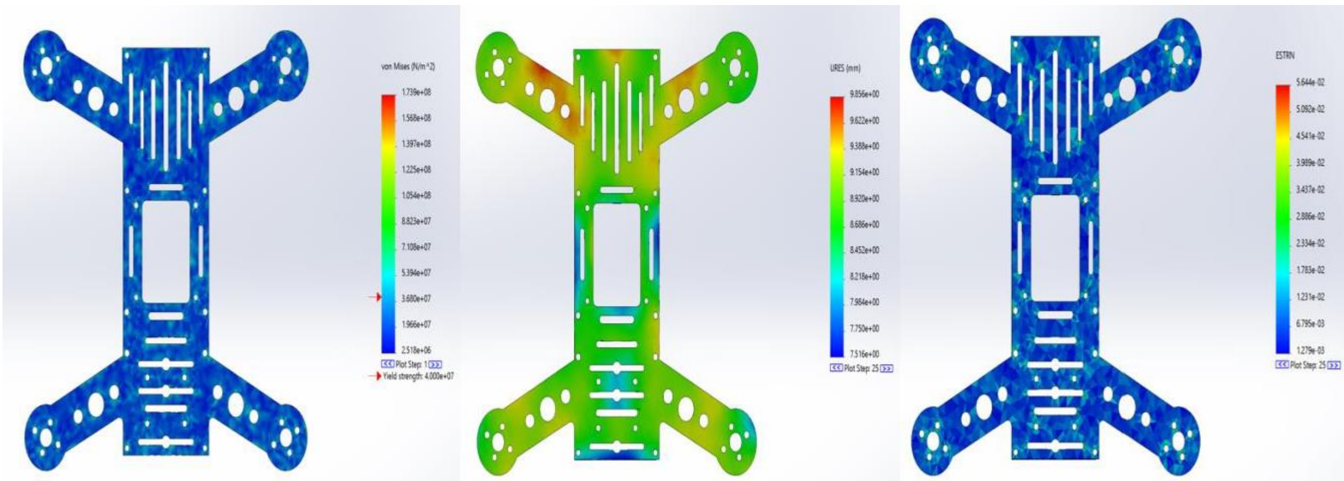
In figure 19 (a), it shows that the yield strength of the material is 45 MPa, and after the drone is dropped



from a height of 100 meters the von Mises stress is around 45.2 MPa, which means that von Mises stress > The yield strength then the material will yield. In figure 19 (b), it shows that the minimum displacement is 8.726 mm and the maximum is 10.16 mm. The red area shows where it is going to deform. However, from the colors, we can see that the displacement of the drone at a height of 100 m is in between. From figure 19 (c), we can see that the minimum and maximum strains are 1.046×10^{-3} and 4.484×10^{-2}.

c) ABS.

In figure 20 (a), it shows that the yield strength of the material is 40 MPa, and after the drone is dropped from a height of 100 meters the von Mises stress is around 41 MPa, which means that von Mises stress > The yield strength then the material will yield. In figure 20 (b), it shows that the minimum displacement is 7.516 mm and the maximum is 9.856 mm. The red area shows where it is going to deform. However, from the colors, we can see that the displacement of the drone at a height of 100 m



is in between. From figure 20 (c), we can see that the minimum and maximum strains are 1.279×10^{-3} and 5.644×10^{-2}.
Figure 20: (a) Von Mises Stress, (b) Displacement, and (c) Strain in ABS

3. Propeller

The quadcopter's one of the most crucial parts are the propellers. My craft's wings are these spinning blades which lift the system into the air by creating an airflow. There are many different sizes and shapes but the same overall purpose that the drone propellers come with; however, each's flight characteristics can be different dramatically.

a) Pitch: is known as the propeller's traveling distance per each revolution. Frequently, it depends on what the specific application is for a quadcopter platform to determine the correct pitch. Lower pitch generally leads to less turbulence and more torque for lifting; therefore, it relieves how hard the motors must work to lift heavy payloads resulting in a flight time increase because less current is drawn by the motors from the battery. Higher pitch propellers can move more air, but they create less torque and more turbulence.

b) Diameter: typically, a propeller blade with a larger diameter permits more contact with the air. This latter has a relation with the flight efficiency, when there is a small decrease or increase in diameter, it can change the efficiency of the drone performance. There is a tendency that when hovering, larger propellers are more stable than smaller ones. Nevertheless, less effort is required for the smaller propeller blades to slow down or speed up than larger ones, which make them more responsive. As said previously, larger propellers with low pitch are better suited for aerial video cameras and lifting heavy payloads while smaller propellers with high pitch are more appropriate for quick and fast manoeuvres.

I made a simulation of the propeller in SolidWorks using Computational Fluid Dynamics (CFD), but before, I had to import a propeller to the Software. The propeller used is shown in the figure below [2].

Figure 29: Propeller Model Used in the Simulation

Engineers use myriad of analysis methods to better understand the world's impact around us on their designs. One of the best and a key analysis method that is used to analyze and solve problems, which involve the fluid flow impact like gases or liquids is Computational Fluid Dynamics. Many industries use CFD to solve a wide range of engineering problems, including aerodynamics and aerospace analysis, high-tech electronics cooling, combustion and engine analysis, industrial systems design, and many others.

The figures below show both the velocity and pressure trajectory plot which is more useful for showing behaviour over the full length of the propeller at any given time. A trajectory plot that uses one of the system planes as a starting point reference that the flow passes through is easy to set up after solving.

4. Electrical Design

To have a safe and smooth flight, all drone components and parts are vital. When knowing the drone components, the user can have more confidence while flying it. After knowing each drone component, it will help the user to get to the bottom of any flight issue.

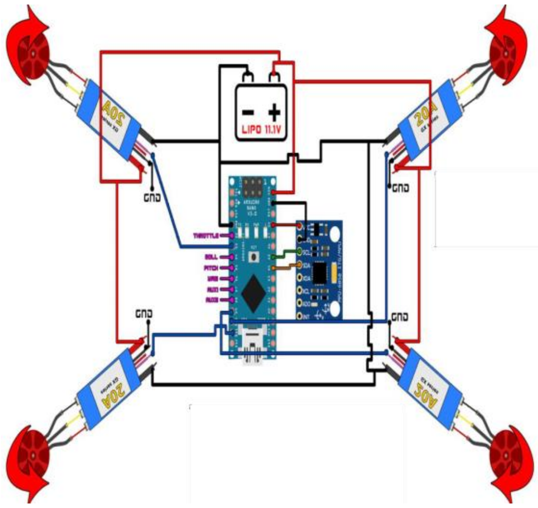


Figure 31: Quadcopter Electrical Connections Schematics [2]

a) BLDC Motor

Brushless motors are brushless outrunner motors or DC electric motors, which are also known as ECMs (Electronically Commutated Motors). Those motors are synchronous, powered by an electric DC source through an integrated inverter switching power supply that produces an electric alternating current (AC) signal to drive the motors. This latter implies a bi- directional current with no restriction on waveform rather than a sinusoidal one. The BLDC motors I chose to work with are 1000 kV ones made specifically for multirotor and quadcopters. They provide power, high performance, quality, dependability at an affordable price, and brilliant efficiency. They are perfectly suited for medium size drones with propellers of 8 to 10 inch. Once ordered, they come with power leads, prop adapters, and mounting bolts as shown in the figure below. Each 30A ESC should be used to drive each motor [3].

Figure 32: A 1000KV BLDC Motor [3]

These kinds of motors were made with wire wound stator poles and a permanent magnet rotor. The

attractive magnetic forces between a rotating magnetic field, which is induced in the wound stator poles, and the permanent magnetic motor convert the electrical energy into a mechanical one.

There are 3 electromagnetic circuits that are commonly connected to a point, and each one of them is divided in the centre; hereby, allowing the permanent magnetic rotor to move amidst the induced magnetic field.

b) Electric Speed Controllers (ESCs)

ESC or an electronic speed controller is a device installed in a remote-controlled model to control the speed and direction of a brushless motor.

Each one of them has an output for a motor and an input for a battery. Four of them are required to control each motor.

Figure 33: Electronic Speed Controller (ESC) [4]

c)Battery

Li-Po batteries currently dominate the market due to their high current discharge and high energy density when it comes to lightweight drones. They are composed of many cells connected in series but rarely in parallel, which are denoted respectively by S or P. Depending on the charge's state how the cell voltage changes; nonetheless, there is going to be permanent damage when discharging a Li-Po cell below 3V. Hence, discharging about 20% of the battery is recommended, which gives an 80% depth of discharge. Besides, these batteries are characterized by a C rating, which identifies the maximum drawn current continuously, and their capacity in mAh. Obviously, this shows that maximum discharge current cannot be dependent on the battery capacity.

In this experiment, a high amount of current is needed for the brushless motors I have used. Therefore, I chose to use a 3 cell 3300 mAh 11.1 V Li-Po battery that can supply roughly 3A current constantly (figure 33). This latter is not heavy and provides sufficient current, which is ideal for this application. Unlike Li-Po, NiMH is cheaper but much heavier. These kinds of batteries (Li-Po) vary from single 3.7 cells up to 37V 10 celled. The most well-known one is the 3SP1 that is three celled and is 11.1V.

Figure 34: 3300mAh 3 Cell Li-Po Battery [5]

5. Cost Analysis

The components and the materials are mentioned in detail as shown in the table below as well as their estimated or respective costs to draw a simple cost analysis of the project.

Component/Material	Price in MAD	Quantity	Total Price in MAD
The frame was laser cut with acrylic. (plexiglass) material	250.00	$1m^2$	250.00
1045 Propeller Pair (CW and CCW)	30.00	2	60.00
1000kV BLDC Motors (A2212/13T)	150.00	4	600.00
30A ESC	120.00	4	480.00
3300mAh 3 Cell Li-Po Battery (Venom)	600.00	1	600.00
Arduino Nano Board	50.00	1	50.00
MPU-6050 IMU	70.00	1	70.00
HC-05 Bluetooth Module	50.00	1	50.00
Total Cost in MAD	**2160**		

IV. Conclusion and Future Work.

This capstone project was one of the golden opportunities that prompted me not only to gain knowledge on different topics and learn a fair number of new technologies but also put them into practice. It was a great way for me to apply all the skills and knowledge I have acquired throughout my undergraduate degree in general engineering. I was able to apply the engineering development process on a real-life project. I managed to conduct a feasibility study, gathering requirements by prioritizing them, designing and implementing the project, and eventually testing it.

During this capstone project, I became much more familiar with the quadcopter flight dynamics and many software, such as SolidWorks, MATLAB, Gazebo, Proteus, and Multiweek. I used SolidWorks to work on the mechanical part of my project to determine the best available material to use and to see the air's velocity and pressure impact on the propeller. These were done by making different simulations and analyses, such as the linear static analysis (to generate the Von Mises stress, displacement, strain and factor of safety), the drop test analysis (to see which material would withstand falling from a height of 100 meters), fatigue analysis (to determine the damage percentage and life cycles), and the flow simulation (to simulate the air flows through and around the propeller to calculate its capabilities and performance).

MATLAB was used to generate quadcopter thrust while flying along with its angular velocity and displacement. In addition, I made a sketch connecting the electrical components using Proteus so that I can upload the code from Multiweek to the software and simulate it. Finally, Gazebo was used to simulate virtually how my system would react in any environment. Not to mention that a quadcopter prototype has been successfully achieved.

I can never say I have learnt much or enough as I will always strive to learn more. Learning never ends and I do not see this project as complete. I aim to develop it further and once fully completed; a final version will be published online for free.

The principal work to be done next is to ensure the drone's smoothness and stability. Besides, the feasibility of using the image processing has been investigated. The idea is to enable the drone to avoid obstacles and recognize people's faces to identify missing people, civilians, and criminals. Thus, working on this will enable me to eliminate criminal activities; especially, that there is a massive increase in crime rate in Morocco and other countries.

In addition, this can be used in favor of many institutes to record attendance by detecting faces without wasting time or effort. This is only one of many other applications that this general- purpose drone could be used to accomplish, which could have a huge impact on societies.

V. Acknowledgement.
We would like to thank several individuals who in one way or another contributed and extended their help in the preparation and completion of this study. Our sincere thanks to Dr. D.K Bhalla whose motivation and guidance has been our inspiration in the completion of this research work. This research work would not have been possible without his help and the valuable time that he has given us amidst his busy schedules. My utmost gratitude to Professor Dr. Rupak Deb, Mechanical HOD. Lingaya's Vidyapeeth, Faridabad for providing necessary advice and cooperation throughout my study. My sincere thanks to all my friends at Lingaya's Vidyapeeth, Faridabad for making my stay on the campus a pleasant one. The co-operation shown by them is worth noting. Lastly. I would thank my parents and the almighty God for giving me support and courage throughout this study.

VI. References.

[1] K. Dragatis, "Free CAD Designs, Files & 3D Models: The GrabCAD Community Library," Free CAD Designs, Files & 3D Models | The GrabCAD Community Library, 23- May-2017. [Online]. Available: https://grabcad.com/library/wooden-drone-frame-1. [Accessed: 12-Nov-2020].

[2] Electronoobs.com. 2020. Arduino Based Drone. [online] Available at: <https://www.electronoobs.com/eng_robotica_tut5_3.php> [Accessed 8 December 2020].

[3] G. Wankhade, "Free CAD Designs, Files & 3D Models: The GrabCAD Community Library," Free CAD Designs, Files & 3D Models | The GrabCAD Community Library, 04-Nov-2020. [Online]. Available: https://grabcad.com/library/propeller-441. [Accessed: 28- Nov-2020].

[4] "1000 Kv A2212 Brushless Motor," Magento Commerce. [Online]. Available: https://www.silverlineelectronics.in/1000-kv-a2212-brushless-motor.html. [Accessed: 01- Dec-2020].

[5] "Skywalker 30A Esc Brushless Motor Electronic Speed Controller - Best Price," https://www.matiot.com/. [Online]. Available: https://www.matiot.com/skywalker-30a-esc-brushless-motor-electronic-speed-controller. [Accessed: 02-Dec-2020].