Design and Manufacturing of X-Shape Quadcopter

Khaled Hassan Mostafa[1], Ayman Shehata Thabet[2], Abdelrady Okasha Elnady[3*]

Mechatronics Department, Faculty of Engineering, October 6 University, Egypt
*Corresponding Author

Received: 04 April 2022/ Revised: 13 April 2022/ Accepted: 21 April 2022/ Published: 30-04-2022

Abstract— *A quadcopter is a form of unmanned aerial vehicle with several rotors. Surveillance, military operations, fire detection, agriculture, spyware, and a variety of other applications are all new to it. Because of their dependability, cost effectiveness, and multi-functionality, they are frequently used in many locations. This article details the design process, including component selection and manufacturing of X-shape quadcopter.*

Keywords— 3D printing, manufacturing, Quadcopter, x-shape.

I. INTRODUCTION

A quadcopter, often known as a quad rotor helicopter or quad rotor, is a multirotor helicopter with four rotors that lift and propel it. Quadcopters are categorised as rotorcraft rather than fixed-wing aircraft since they employ a set of rotors to generate lift (vertically oriented propellers). Quadcopters, unlike most helicopters, have two sets of identical fixed pitch propellers: two clockwise (CW) and two counter-clockwise (CCW) (CCW) as shown in Fig. 1. The lift and torque are controlled by varying the RPM. Changes in the rotation rate of one or more rotor discs change the torque load and thrust/lift characteristics of the vehicle, allowing it to be controlled [1].

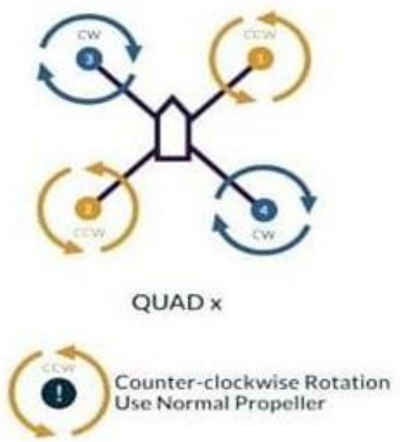

FIGURE 1: Propeller configuration of quadcopter

II. QUADCOPTER FRAME TYPES

There are a variety of frame styles, all of which are determined by the position of the arms as well as the size and shape of the electronics carriage. Each frame type is described in detail below, along with a graphical sample [2]

2.1 True-X shape

The X-frame is the most symmetrical, with more weight concentrated at the centre of gravity, which improves stability but also increases the quadcopter's vulnerability to aerodynamic disturbances. Because the arms are sandwiched between the main plates, this design necessitates the use of more material. In this design, there isn't much room for hardware. This will be a problem for the project because the motor and fuel tanks will take up a lot of room, and the flight controls and cargo must also fit in. Because the flight controller and camera are so close to the motor, the X-frame would compel all of these components to be virtually on top of each other, increasing the vibration problem. Stacking all of the components will necessitate more structural material, increasing the quadcopter's weight. The shortage of space around the motor would make it difficult to integrate the components that drive the rotors, despite the design's simplicity. The True X is shaped in the same way it sounds, with X geometry and a motor at each end of the arms. As shown in Fig. 2, the perpendicular distance between the centres of each motor is equal, giving the quadcopter the same amount of stability on all axes [3].

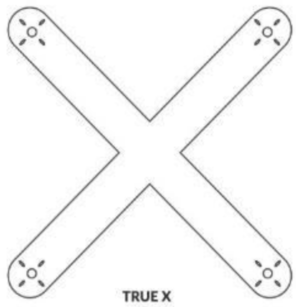

FIGURE 2: True X-shape quadcopter

Table 1 lists the benefits and drawbacks of the True X-shape quadcopter

TABLE 1
BENEFITS AND DRAWBACKS OF THE X-SHAPE QUADCOPTER

Description	Pro	Con
Little space for hardware		X
Good stability and control	X	
Higher derivation complexity due to lack of mounting space		X
More weight due to sandwiching mounting structures		X

2.2 Dead Cat

Larger quadcopter designs tend to embrace the dead cat look. Its goal is to obscure the propellers from view of the on-board HD camera by increasing the perpendicular distance between the two frontal motors, as shown in Fig. 3.

FIGURE 3: Dead Cat-like quadcopter

FIGURE 4: H style quadcopter

2.3 H-Shape

Another antique quadcopter design style is the H style. The arms of a H quad are positioned in front of a long "bus" shaped carriage as shown in Fig. 4. The H quad has recently fallen out of favour due to its hefty dimensions and odd configuration.

2.4 Hybrid (Stretch) X Quadcopter

The stretch X is a wide X that has been rotated as shown in Fig. 5. Racers that want additional stability on the pitch axis, which might help with control when the quadcopter is racing at high speeds, prefer the stretch X.

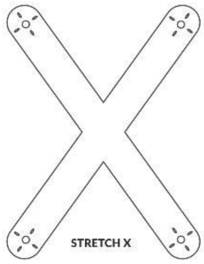

FIGURE 5: Stretch X quadcopter

FIGURE 6: Plus shape quadcopter

2.5 Plus Shape Quadcopter

The footprint of a plus frame is the same as that of an X frame flipped 45 degrees as shown in Fig. 6. A plus frame has the advantage of each motor being responsible for rotating movement in only one axis, theoretically allowing for finer control. Plus frames, on the other hand, are more prone to breaking because most impacts only involve a powerful contact to the front arm.

III. COMPONENT'S SELECTIONS

3.1 DC Brushless Motors

The propellers are spun by the motors to provide lifting thrust to the drone. Brushless DC motors are almost always used in drones because they give better thrust-to-weight ratios than brushed DC motors. Kv ratings and current ratings are the most common ratings given to motors. For 1V of applied voltage, the Kv rating shows how rapidly the motor will spin (RPM). The maximum current that the motor can safely draw is indicated by the current rating. As a result, we chose a Brushless DC motor of type (MT 2204-2300 Kv) for our project. Also, there are two types of brushless motors: in-runner (shown in Fig. 7) and out-runner (shown in Fig. 8), each with its own set of characteristics. In-runner brushless dc motors have low torque and high speed, whereas out-runner brushless dc motors have high torque and low speed. Since we require high torque but not high speed, we will use an out-runner brushless motor [4].

FIGURE 7: in-runner brushless motor

FIGURE 8: out-runner brushless motor

The characteristics of the chosen motor are listed in Table 2.

3.2 Propeller

A propeller is a fan that uses rotational motion to generate thrust. Propellers are generally characterized by their diameter and pitch, and are represented as a product of diameter and pitch. There are several varieties of propellers, the most common of which are nylon and carbon. For our project, we chose a plastic propeller. The dimensions of each propeller are inscribed on it, for example, 10 *4.5, which implies the length is equal to 10 and the pitch is equal to 4.5, as seen in Fig. 9 [5].

TABLE 2
CHARACTERISTICS OF THE SELECTED MOTOR

Motor KV (RPM/V)	2300 KV
Maximum Thrust	450 gm
ESC	18A
Li-PO Batteries	2-3S
Propellers	6 - 8 inch
Weight (gm)	25gm
Power	51 Watt

FIGURE 9: Propeller of type (10*4.5)

3.3 Electronic speed controller

The electronic speed controller regulates the motor's speed or tells it how fast to turn at a specific time. Four ESCs are required for a quadcopter, one for each motor. Through either control appropriation board, the ESCs are officially connected to the battery. Each ESC has a current rating that indicates the maximum current it can provide to the motor without overheating. ESCs must be chosen carefully to guarantee that the motors receive enough current. Based on our estimates, we chose Simonk 30A ESC (Fig. 10) for our project. The characteristics of the chosen ESC are listed in Table 3.

FIGURE 10: ESC 30A

TABLE 3
CHARACTERISTICS OF THE ESC

cont. Current	30A
BEC Output	5V 2A
LiPO Batteries	2-3S
Weight	25gm
Size (L*W*H)	32*24*7mm

3.4 Battery

The battery provides electrical power to the aircraft's motors and electronic components. Lithium polymer batteries (Li-Po) are the most common battery used in drones due to their small weight, high energy density, longer run periods, and ability to be recharged, but they have the drawback of not waking up if the charge is totally depleted. We choose Battery (Zippy 3300) in Fig. 11 based on our calculations. Table 4 lists the characteristics of the chosen battery [6].

FIGURE 11: Battery

TABLE 4
CHARACTERISTICS OF THE CHOSEN BATTERY

Capacity	3300mah
Voltage	3s/11.1V
Discharge	40c constant/50c Brust
Weight(gram)	286g
Dimensions(L*W*H)	136*45*24mm

3.5 Video link

In order to do image processing, we must utilize a camera as well as a video link. For our project, we used a video link of type (Ts 832) as shown in Fig. 12.

FIGURE 12: Ts 832-video link

3.6 Remote control

The basic goal of R/C is to control the quadcopter remotely, and there are two conditions to consider while choosing the right one. The first is the amount of channels you'll require; in our case, we'll require four [X for Roller, Y for Pitch, Z for Yaw, and Throttle (to control motor speed)]. The range of control is the second criterion. It's a budget-friendly six-channel transmitter for models that require it. The transmitter contains an easy-to-reach retract switch and proportional flap dial, as well as elevon and V-tail mixing and servo reversing [7]. The R/C transmitter and receiver are shown in Fig. 13. Its main characteristics were as follows:

(1) 6-channel 2.4GHz transmitter.

(2) Servo reversing function.

(3) Elevon and V-tail mixing options.

(4) Built-in antenna.

(5) Basic models control.

(6) FHSS 2.4 GHz Technology.

(7) 6-channel receiver.

FIGURE 13: R/C receiver and transmitter

3.7 Camera

Micro FPV Camera is selected; it has an input voltage of 5V, a resolution of 1024, a dimension of 21*19*17 mm, and a weight of 8 gm.

IV. PRELIMINARY DESIGN

4.1 General equation

A rough weight estimate is calculated in this section. The general weight estimate equation is

$$WGL = WE + WF + WPL + WCrew \tag{1}$$

WGL stands for the ground launch weight. WE is the empty weight. WF stands for "Weight of Fuel". The Payload Weight (WPL) is the total weight of the payload. The crew weight is W_{Crew}.

In drones, the weight of the fuel and the weight of the crew will be zero. As a result, equation (1) becomes:

$$WGL = WE + WPL \tag{2}$$

The empty weight (WE) includes the following components:

$Weight\ of\ Battery$ = 286gm

$Weight\ of\ 4\ Dc\ motors$ = 4∗25=100gm

$Weight\ of\ ESC$ = 4∗25=100gm

$Weight\ of\ 3D\ Printed\ Frame$ = 526gm

So, the total empty weight becomes $\boldsymbol{W}$E= 1012gm

The payload W_{PL} components includes:

Wight of video link = 22gm.

Wight of camera = 8 gm.

So, the total weight of the payload WPL = 30 gm

The ground lunch load W_{GL} will equal:

W_{GL}=1045gm.

4.2 Estimation of brushless DC motor

W_{GL} = 1045gm

The total thrust =2090 gm

Thrust for each motor = Total thrust / Number of motors = 522.5 gm

V. FRAME DESIGN

The difficulty lies in selecting the appropriate material for the quadcopter's construction, as it is necessary to obtain a material with sufficient strength and hardness to withstand the impact of motors, as well as the weights that will be carried by the quadcopter, such as the camera, battery, and other items, and to be able to take off without difficulty.

The frame design process is split into two parts: the first is choosing the material, and the second is choosing the fundamental dimensions. Another consideration in the design process is to make the angle between the axes of the motor positions 90 degrees, since this will improve the quadcopter's balance and stability. As shown in Fig. 14, the quadcopter's dimensions are 35 cm (Width)*35 cm (Length)*8.6 cm (Hight).

The quadcopter arm's frame is truss-style; a truss provides a solid form capable of carrying significant external load over a long span, with component sections strained predominantly in axial tension or compression. Individual parts meet at truss joints, also known as panel points. The top and bottom chords are the connected sections that comprise the top and bottom of the truss, respectively. The web of the truss, as shown in Fig. 15, is made up of sloping and vertical parts that link the chords.

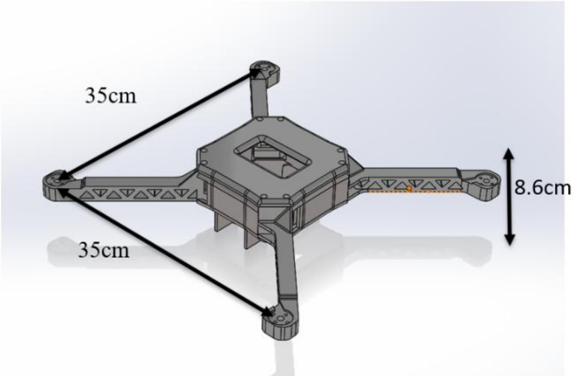

FIGURE 14: Configuration of Quadcopter

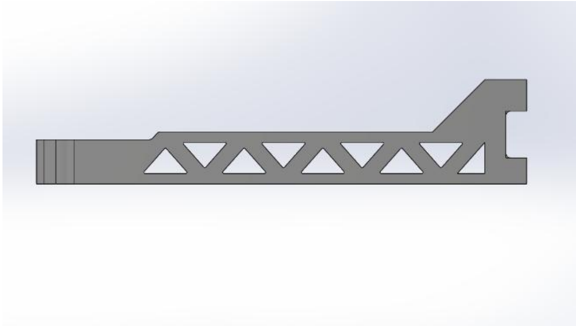

FIGURE 15: Quadcopter arm's frame

The motor's base requires some space to be more stable because of the vibrations that may occur during flight, and we provide space for the motor's wiring as illustrated in Fig. 16.

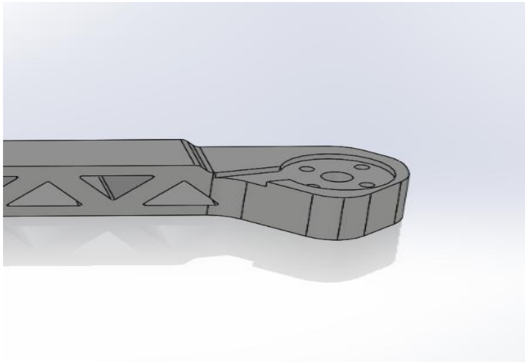

FIGURE 16: Motor's base

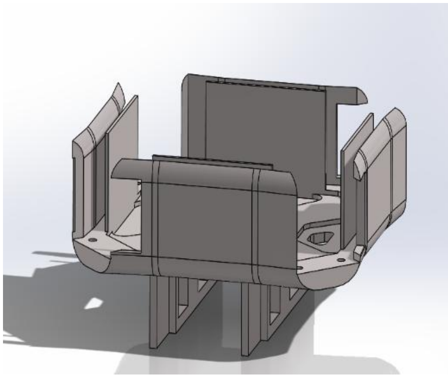

FIGURE 17: Quadcopter body

The main body of the quadcopter is designed as indicated in Fig. 17, and the battery is placed in the gap between the skids. In the main body, drone accessories such as ARDUPILOT, ESCs, and cameras are coordinated.

The final arrangement of our drone is shown in Fig. 18.

FIGURE 18: Final arrangement of our drone

VI. AIRFRAME MANUFACTURING

The quadcopted airframe is manufactured using 3D printing technology. The 3D printing process builds a three-dimensional object, usually by successively adding material layer by layer, which is why it is also called additive manufacturing.

6.1 3D Printing

3D printing is a new way of manufacturing products. The general term used to describe 3D Printing in all its guises is Additive Manufacturing. As mentioned previously a product is built by adding layers. The definition and quality of the product is dependent on the size of the extruder or layering height as well as the resolution of the design software [8]. The 3D model of the airframe is drawn using Solid Works 2018.

In this Project PLA material is used for Quadcopter frame manufacturing. PLA is a common thermoplastic polymer derived from natural sources such as corn starch or sugar cane, in contrast to many other thermoplastics which are produced from non-renewable sources such as petroleum. From automotive to food packaging, a range of industries are using PLA to produce 3D printed products [9, 10]. The advantages of PLA are:

- Low printing temperature
- Ease to use
- Variety of color and blending options
- Easy post-processing

Although 3D printer (Fig. 19) settings vary depending on the type and blend of PLA filaments, there are some basic requirements and specifications listed below to ensure a successful printing process:

- PLA melting point: 150-160°C
- PLA printing temperature: 180-230°C
- Heated print bed: optional
- Cooling: part cooling fan is necessary
- Enclosure: not necessary
- Filament storage: airtight container

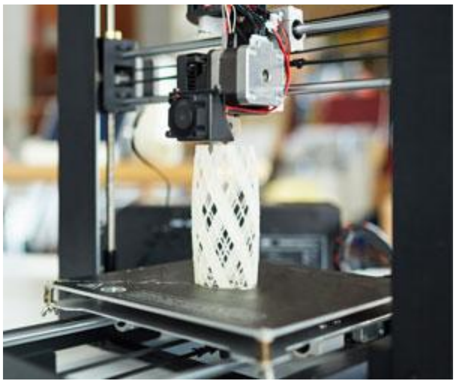

FIGURE 19: 3D printer

Fig. 20 shows some components of airfame using 3D Printer. Fig. 21 shows the final arrangement of the present X-Quadcopter.

FIGURE 20: 3D printed airframe parts

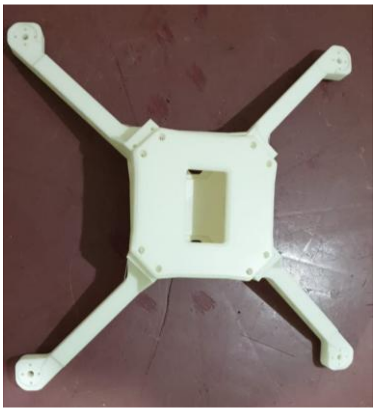

FIGURE 21: Final arrangement of the present X-Quadcopter

VII. CENTER OF GRAVITY ESTIMATION

The suitable location of the center of gravity is to be in mid of drone that's make control on drone easier and it make drone stable.

So, depending on components weight, it distributed on the drone such that position of center of gravity remains at mid point. The isometric view is shown in Fig. 22.

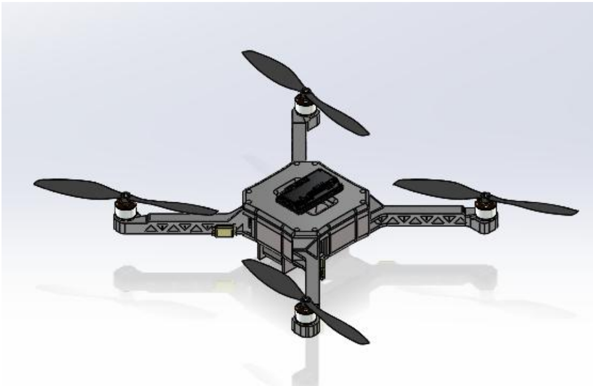

FIGURE 22: Isometric view

VIII. CONCLUSION

Using Solid Works 2018, the frame of quadcopter is designed and manufactured using 3D printing technology with PLA-Plus filament. The main components are chosen depending on calculations. Based on the calculations, the suitable distribution of the components is done to reach the best center of gravity point to get the best balance possible.

ACKNOWLEDGMENT

We'd like to express our thankfulness and appreciation for Assoc. Prof. *Abdelrady Okasha Elnady*, whose advice, encouragement, and support have been vital throughout this project. We admire how compassionate and instructive you are. Thank you for everything you taught us, in our academic life even though in our daily life. These will stay with us for the rest of our life. We consider ourselves extremely lucky to be able to work under the guidance of such a dynamic personality.

REFERENCES

[1] Hoffmann, G.M.; Rajnarayan, D.G.; Waslander, S.L.; Dostal, D.; Jang, J.S.; Tomlin, C.J. (November 2004). "The Stanford Testbed of Autonomous Rotorcraft for Multi Agent Control (STARMAC)". In the Proceedings of the 23rd Digital Avionics System Conference. Salt Lake City, UT. pp. 12.E.4/1–10.

[2] https://www.getfpv.com/learn/new-to-fpv/all-about-multirotor-fpv-drone-frame.

[3] Padmaraja Yedamale, "Hands-on Workshop: Motor Control Part 4 -Brushless DC (BLDC) Motor Fundamentals," Microchip AN885, 2003

[4] M.F. Shariff, Propeller Aerodynamic Analysis and Design, AERO2365 Thesis, RMIT University, 2007.

[5] Bruno Scrosati, K. M. Abraham, Walter A. van Schalkwijk, Jusef Hassoun (ed), Lithium Batteries: Advanced Technologies and Applications, John Wiley & Sons, 2013 ISBN 1118615395, page 44.

[6] J. David Goodman (September 5, 2013). "Remote-Controlled Model Helicopter Fatally Strikes Its Operator". New York Times. Retrieved 2013-12-05.

[7] Azman, Abdul Hadi. "CAD tools and file format performance evaluation in designing lattice structures for additive manufacturing."Jurnal Teknologi 80.4 (2018).

[8] Gina L. Fiore; Feng Jing; Victor G. Young Jr.; Christopher J. Cramer; Marc A. Hillmyer (2010). "High Tg Aliphatic Polyesters by the Polymerization of Spirolactide Derivatives". Polymer Chemistry.

[9] Rafael Auras; Loong-Tak Lim; Susan E. M. Selke; Hideto Tsuji, eds. (2010). Poly (Lactic Acid): Synthesis, Structures, Properties, Processing, and Applications.