"Quadrotor – An Unmanned Aerial Vehicle"

Mr. Kalpesh N. Shah[1], Mr. Bala J. Dutt[2], Hardik Modh[3]

[1,2] Assistant Professor, [3]U.G. Student
Dept. of Mechanical engineering, A D Patel Institute of Technology, New V.V.Nagar, Anand, Gujarat, India
[1]me.kalpeshnshah@adit.ac.in, [2]me.baladutt@adit.ac.in, [3]hbmodh93@gmail.com

***Abstract* - The usage of Unmanned Aerial Vehicles (UAVs) has grown drastically because of their ability to operate in dangerous locations while keeping their human operators at a safe distance. UAVs are widely used in military operations nowadays because of their reliability, cost effectiveness and multi-functionality. The problem we posed in this paper is the weight lifting capacity of UAVs. Improvement in weight lifting capacity may leads to adding a more function in account of UAVs. To validate this proposal, we considered many different structures of UAVs and choose Quadrotor. The payload of our Quadrotor is around 4 kg which adds function of weight lifting in military operations as well as industrial applications. Calculation of aerodynamic drag-lift forces has been done. The stresses generated in the body of quadrotor is not more than 22.5 MPa in "Box" sectional chassis and 22.2 MPa in "C" Sectional chassis as per the practical testing. To validate these results, the stress analysis of two types of body of quadrotor ("Box" and "C" section) is carried out in ANSYS static structural solver. As per the Static Structural solver the stress generated are 15.4 MPa and 16.97 MPa in "Box" and "C" sectional chassis respectively. Further analysis and fabrication of model is under process. Quadrotor can be used in safety, inspection of tool in construction industry, toxic material handling, transmitting important and emergency orders.**

***Keywords* - Quadrotor, Unmanned Aerial Vehicle (UAV), Aerodynamic drag-lift forces.**

1. INTRODUCTION

In nowadays the development of small UAV is under the interest of many researchers and want to explore the application. There is currently a large range of projects and research topics emerging in this field. Preliminary research has shown that the most versatile and mechanically easy to construct UAV is a quadrotor helicopter. This is due to the fact that quadrotor aerial robot is an automatic system which is an unmanned VTOL (vertical take-off and landing) helicopter. Quadrotors can be controlled by varying the speed of the four rotors and no mechanical linkages are required to vary the rotor blade pitch angles as compare to a conventional helicopter.

2. CONSTRUCTION

Quadrotor consisting of a main body having four arms centrally connected to each other and four DC brushless motor attached to each free end of arm. Quadrotor consists of four rotor/propeller attached to each motor shaft. Four rotors with fixed angles represent fixed pitch to generate equivalent force at each end to lift the body and payload. All DC brushless motors are attached to electronic speed controller to control speed of each individual motor. Four electronic speed controllers connected with each other by parallel connection in to power distribution board. A battery is used as power source. The rotation of propeller is controlled by remote controller (RC).

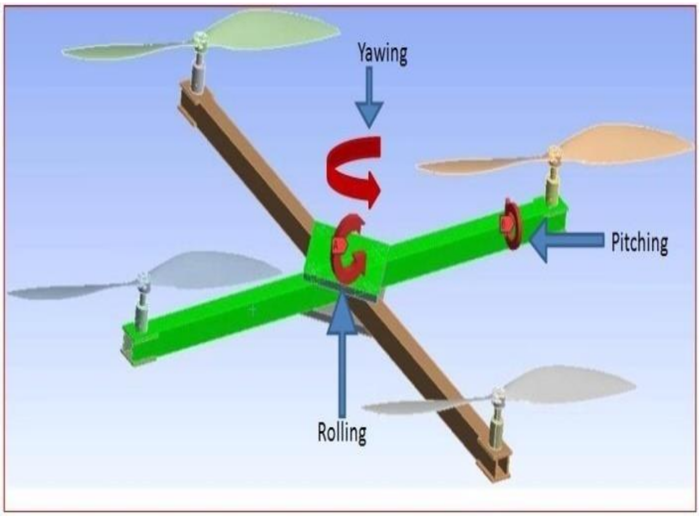
3. THEORY

All DC brushless motor attached by parallel connection with other motors. Power distributed to power distribution board from battery. Further the power distributes equally to four electronic speed controllers and then goes in to each DC brushless motors. Accelerometers will measure the angle of Quadrotor in terms of X, Y and Z axis and accordingly adjust the RPM of each motor in order to self stabilize by it-self. The stability is provided by setting the direction of rotation clockwise of one set of opposite motors and counter-clockwise of other set of motors which nullifies the net moment and gyroscopic effects.

By using this principle one is able to adjust the speed and can get desired speed of each individual motor in order to get desired yaw, pitch and roll. RPM of the shaft of a motor is a function of voltage provided to that motor. Roll and pitch can be controlled by changing the speed of the appropriate motor, while yaw control involves proper balancing of all four motor results in to change in moment and force applied to take appropriate turn. Controlling of quadrotor involves different four states.

3.1. Upward motion (Z direction): The force required for this motion is known as lift force and generated by thrust produced by four propellers rotating at same speed.

3.2. Yaw Motion (ψ): This motion is attained by increasing speed of appropriate set of motors. By generating couple of force from two neighbour motors, yawing can be achieved.



[Figure 1: Gyroscopic Effects]

3.3. Pitch Motion (ɵ): This motion can be attained by generating couple of forces from the set of motors in the direction of the movement (Front and rear motor).

3.4. Roll Motion (Φ): This motion can be attained by generating couple of forces from the set of motors in the direction other than the direction of motion (Left and Right side motor.

4. LITERATURE STUDY

Many research have been made on quadrotor by worldwide researchers. Pounds et al. presented fundamental dynamics analysis and control approaches through the design of a large-size quadrotor with total weight of 4kg and capable of lifting a 1kg payload which was deemed necessary for the computers and sensors of the time [4], [5].

Bouabdallah and Siegwart accomplished impressive results in control and state estimation with a quadcopter platform and a ground station. Image data was sent to the ground station, processed, and commands were transmitted back to the flying vehicle over a radio communications link [6].

Javier, Masoud and Bruce presented the usability of quadcopter as safety inspection tool in industries. They focused on the construction industry. Their study proposed the use of a quadcopter to fly over the construction jobsite and provide the safety manager with real time information about what is happening on the jobsite. Also through the communication tools embedded in the quadcopter, safety manager can interact directly with workers [7].

Tsubasa, Andrew, Ehrich, Eric, Paul and John proposed the concept of non-destructive evaluation of structures like bridges, where using equipment mounted on a highly stable and mobile UAV like quadcopter is more efficient and economical. The stability issue is addressed immediately by the quadcopter concept; however there was a need of a structure that was stiff, lightweight and less complex [8].

Recent case of using quadcopter for civilian application is when tsunami stuck the Fukushima nuclear power plant in Japan on the 11 th March, 2011.Dut to very unsafe conditions at the plant, Tokyo Electric Power (TEPCO) used a US-made micro aerial vehicle to photography the nuclear plant from above. The flying robot had already had already been used by the US military to find roadside bombs in Iraq [9].

The practical use of a quad copter was cited in New Zealand to examine the front of the Roman Catholic Cathedral in Christ church that was damaged in the 22 February, 2011 earthquake [10].

Universities and research institutions have started using this quadcopter as an experimental platform in different researches such as autonomous surveillance and navigation [11], human-machine interaction [12], and even as a sport assistant by providing athletes with external imagery of their actions [13].

5. WORKING

The input wireless signal is generated and transmitted by remote controller which is received by receiver on the board. Generally Xbee coordinator is used to transmit signal and Xbee router is used to receive control signal. The microcontrollers decodes the data from the input signal received by router and takes appropriate action. A IMU board consisting of a 3-axis gyroscope and a 3-axis accelerometer is provided to stabilize and balance the body of quadrotor. According to signal received from the remote control, the processor governs the power and voltage from battery to each ESCs by power distribution board. Directional movement can be achieved by decreasing voltage of front motor and increasing the voltage of rear motor. Yawing can be achieved by reducing voltage of inner sided motor and increasing voltage of outer side motor in the direction of turn.

6. COMPONENTS

6.1. Microcontroller: Microcontroller consists of 3-axis gyroscope and 3-axis accelerometer. An accelerometer is a device measures acceleration forces. A gyroscope is a device used primarily for navigation and measurement of angular velocity [15]. 3 axis gyroscope are often implemented with 3-axis accelerometer to provide a full 6 degree of freedom [DOF] motion tracking system.

6.2. DC Brushless Motor: Brushless motors has more advantage compare to brushed motor, force motor and servo motor in terms of comparatively more efficiency, reliability, longer life span, more power, high torque per weight, reduced noise factor, elimination of ionizing sparks from commutator and overall reduction of electromagnetic interface.
6.3. Propellers: Propellers are used to generate aerodynamic lift force. A pair of clockwise rotating and a pair of counter clock wise rotating propellers nullifies the gyroscopic effect of each individual motor. We will be using propellers having diameter of 11 inches and pitch of 4.7 inches/revolution.
6.4. Electronic Speed Controller (ESC): An ESC is an electronic circuit used to vary an electric motor's speed and also acts as dynamic brakes of the system. An ESC controls the brushless motor by converting the supplied DC from the battery into three phased AC. We are using v3.1, 25 A basic Turnigy brushless speed controller.
6.5. Battery (LiPo): Lithium polymer batteries (LiPo) are most popular for powering remote control aircraft due to its light weight, energy density, longer run times and ability to be recharged. We selected zippy 5000mah, 11.1 V, 3 cell, 25 C battery.
6.6. Lippo Alarm: A Lippo alarm is an audible and visual alarm that plugs into battery to provide a voltage warning during flight to land the quadrotor prior to failure due to low voltage.
6.7. Remote controller (RC): A radio control (RC) system needs a transmitter and receiver. Remote controller is used to serve multi purposes like voltage regulation to ESCs, steering control, vertical take-of and landing (VTOL). We are using 6 channel FHSS 2.4GHz Turnigy Remote Controller.

7. FRAME DESIGN AND CONSTRUCTION

As the basic input is high weight carrying capacity, the frame should have low weight and sufficient strength to bear the static and dynamic loading condition without any kind of fracture. The initial work is to design each component parametrically and assemble each component at correct location on frame in modelling software CREO. This is necessary to analyse the strength of body static and dynamic loading and find the directional deformation and stress developed at each point in frame as well as the thrust, acceleration effects in dynamic condition during vertical take-off, yawing and during directional movement.
The first approach to make a frame is the arms of square cross section to get proper mounting points and support for each component on frame. There are two arms of 500 mm connected to each other perpendicularly at centre and clamped by two plates (1 at top and other at bottom) this plates are basic support of all the controllers, battery and power distribution board. The motor is mounted at each end of arms.

7.1 Component with Mechanical properties:

All the components are assembled together in CREO modelling software.

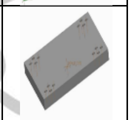
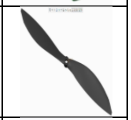
No.	Component	Dimensions (l × b × h) mm	Mass (gram)	Image
1	Box sectional chassis	500×22×18	62.943	
2	Plate	70×70×5	26.744	
3	Motor	27×27(D × H)	79.80	
4	Propellers	11'×4.7'(D×P)	10.83	
5	Bolts	2×25×0.5(D × L × P)	0.7151	

Table 1: Components with Mechanical Properties

Figure 2: Assembly of Quadrotor Frame

Technical details of the assembly:

- ✓ **volume:** 1.6966×10^5 mm^3
- ✓ **mass of structure:** 1.3318 kg

7.2 Analysis in ANSYS14 [Workbench] software:

Static structural analysis provides data of directional deformation under static loading of 5kg containing of various forces like weight of the assembly & thrust force generated by rotors.

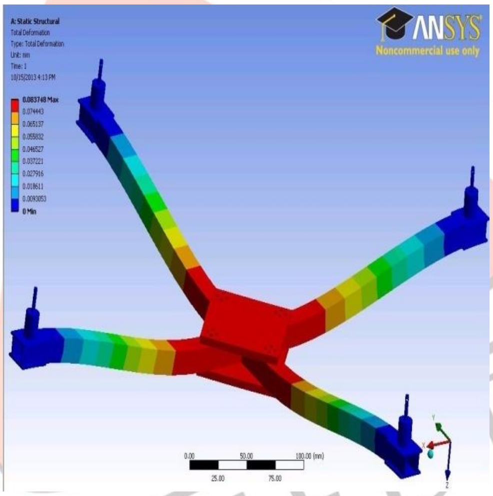


Figure 3: Total Deformation in Static Structural Analysis

Maximum deformation is 0.08374mm.

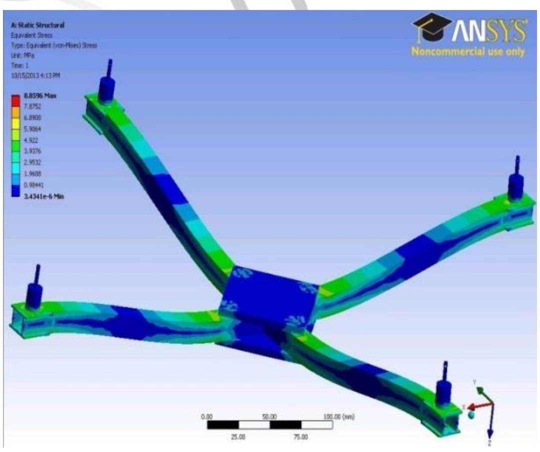


Figure 4: Von-mises Stress developed inside the frame in static structure analysis

Maximum stress is 8.8596MPa.

Von-mises stress developed under consideration of static loading of 5kg can also be calculated in ANSYS software.

7.3 Result:

Comparison	Box Section type chassis	"C" Section type chassis	"I" Section type chassis
Deformation [Analytical]	0.5228 mm	1.1216 mm	- - -
Deformation [Software]	0.16523 mm	0.17748 mm	0.027789 mm
Deformation [Testing]	1.5499 mm	3.8440 mm	- - -
Stress [Analytical]	10.38 Mpa	22.289 MPa	- - -
Stress [Software]	15.399 MPa	36.051 MPa	24.697 Mpa
Stress [Testing]	22.523 MPa	22.225 MPa	- - -

Table 2: Results of analytical calculation, software approach and testing

8. CONCLUSION

The core intension of our project is to study the complete designing process of quadrotor from the engineering perspective and to fabricate a working model of UAV-Quadrotor with improvement in its weight carrying capacity. Our main goal is to fabricate a Quadrotor which can be used for multipurpose application in market, military, commercial and industrial applications like Traffic monitoring and management, Search and rescue operation, Temperature and altitude estimation, Crowd management, Locating forest fire or frost conditions in farmlands, Weather forecasting, post natural disaster, Object identification and Reconnaissance. With the help of our project guides, we have the resources and technical knowledge to successfully complete this project. We chose the UAV Quadrotor for project because of its flexibility, high learning opportunity and potential of future research. This project can go further in variety of research work to integrate various technologies with UAVs to get various useful outputs. This project will be definitely useful to implement new function of high weight lifting in the account of UAVs.

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