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An Experimental Research on Design and Development of Tricopter

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Abstract: ***The paper is giving a detail description on the design and simulation of tricopter. As the tricopter runs on the newton third law of motion and thrust forces so the paper discussed the detail procedure to calculating the principle fundamental forces acting on the tricopter. This research paper presents the design steps for a tricopter with the use of motor, propeller, battery, flight controller and power distribution board. The CAD design of tricopter helps to visualise the major flight component of tricopter and its orientation. The major advantage of this tricopter is that it can balance various flight parameters like aileron, rudder and throttle. The application of this tricopter includes fire service, military surveillance, product delivery system and medico application. The objective is to provide the summary of design, calibration, and fabrication of the tricopter.***

Keywords : Tricopter, Flight controller, Servo control, Calibration, Fabrication

I. INTRODUCTION

To nourished and empowered the civilizations advanced transportation solution have an important role to yield a civilization to a higher level.

The tricopter is an unmanned aerial vehicle suitable for the different demography for instance India is the country of land, distorts, water, hills, mountains and snow lands. The best utilization of tricopter is for the time of epidemic, war and natural calamity where the place is become in accessible to render the service for the victims. The vehicle will be capable enough to reach the places and can connect the services. The main objective is to develop a cost effective, efficient, lightweight, more stable and adaptive vehicle to the environment. Tricopter controlled by a remote controller by a pilot. Camera is located on the tricopter for super vision of the surrounding at any time so that we can take a view by sitting at base station.

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II. LITERATURE REVIEW

In 1923 the first multi- rotor helicopter in which the motor was fixed invented by De Bothezat. The main drawback was unreliability of the vehicle. This technology of tricopter is used by Singapore Police Force (SPF) for easily take –up and landing in vertical direction. Different organization in China uses this UAAV technology for power line inspection.

Tricopter is more stable than a helicopter. It needs agility for multi degree of freedom due to compact body and adequate range.

The applications of tricopter are military, filming, agriculture and search and rescue purpose. Yaw Servo makes yawing faster. Yaw is connected to the rear arm of tricopter, and it is freely moving in both clockwise direction and anticlockwise direction, according to the motion of tricopter arm. Yaw mechanism spline was design for smaller metal gear servos for more valuable but its great design and construction allows to bigger more powerful motors and servos to be installed.

III. DESIGN PRINCIPLE

Tricopter design basically, consists of three arms that are front two arms and tail rear arm. We take first one arm length and we have also taken 16cm length and draw a circle. Then from one arm make another arm at 120 degree angle then draw a circle and rear arm and end tail. We must draw a line at which the two circles are intersecting and we got the dimension of 3 arms with C.G point at the centre of circle. The size of tricopter (UAV) depends onto the surroundings and the impact act on the tricopter. To understand the dynamic variables and effect on tricopter the 6 degree of freedom nonlinear equations are implemented for design of the tricopter.

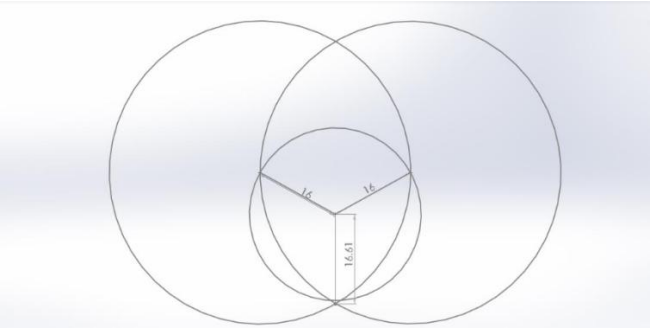


Figure-1: Dimension of tricopter

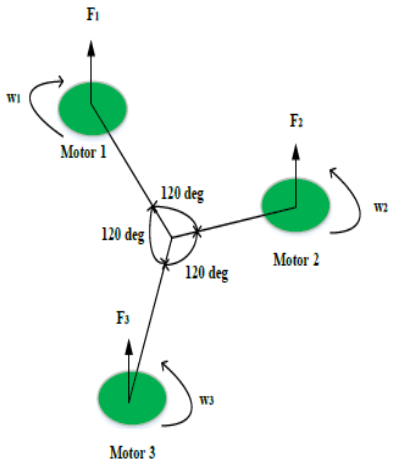


Figure. 2: Angle and rotation of tricopter

It consists of three rotors which are order in a "T" and sometimes in "Y" shape usually 120 degree aside.

Force equation –

$$a=zb-yc-gsin\theta+F_1/m$$
$$b=za-xc-gsin\text{ø}.cos\theta+F_2/m$$
$$c=ya-xb-gcos\text{ø}.cos\theta+F_3/m$$

Where,

F_1, F_2, F3= external forces.
a,b,c =translational velocities.
x,y,z = rotational velocities.
M= Moment of force
θ- Angle of inclination

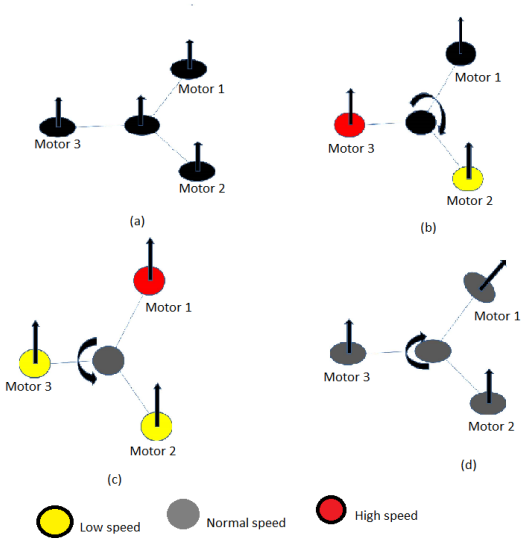


Figure-3: Control and strategies of tricopter

The above figure-3 describes the dynamic behavior of flights where servo motor controls the changes of angle in the tail part.

Tricopter motion can decay in various reasons, these are pitch, altitude, roll, and yaw control. The altitude control can raise the speed of motion with increase in altitude in vice-versa. Roll controls gives the same speed in motor-1. According to the speed of two motors it creates the roll control. Pitch control provides equal angular velocity for front two motors. According to front two motor, motor-1 generate the pitch control. Yaw control is help full for motor-1 where it controls reaction torque and angle of inclination for sudden turning control.

IV. MATHEMATICAL MODEL

When tricopter flies there are some forces acting on it, these are:-

- Drag force [D]
- Thrust force[T]
- Lift force [L]
- Weight force[W]

Due to this force tricopter can be balanced.

$$\Sigma Fy = 0$$
$$\Sigma Fx = 0$$
$$F = ma \text{ [Newton } 2^{nd} \text{ law] (eq.1)}$$
$$a = 0 \text{ [for constant velocity]}$$
$$So, F = 0$$

So the balancing force on the horizontal direction.

$$\text{Thrust force-Drag force} = 0$$
$$So, \quad T-D=0$$
$$T=D \quad (eq.2)$$

In this way horizontal direction.

$$\text{Lift force-Weight force} = 0$$
$$L-W=0$$
$$L=W \quad (eq.3)$$

To maintain the equilibrium of flight at the certain height the thrust force must equal to the drag force and the lift force must equal the weight of the tricopter. In order to gain altitude, the force of lift must be greater than the force due to gravity. Similarly, in order to accelerate the vehicle the force of thrust must be greater than the force of drag.

Tricopter by using solid works

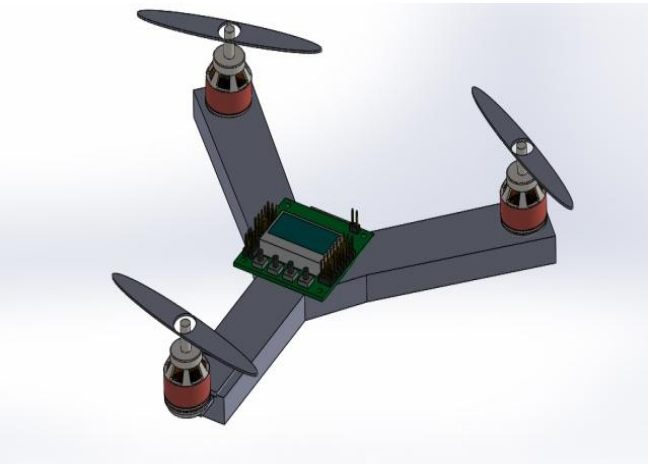


Figure-4: Design of prototype model

V. COMPONENT SELECTION

There are several crucial electrical and electronic component chosen for complete the structure of tricopter. After calculating the thrust power and critical weight for the vehicle, suitable motor and controller are selected based on several parameters. The parameters are like critical speed of motors, span length of the propeller, maximum safety current drawn capacity, multi channel flight controller and capacity rating factor of battery. The distinguished part and their specification are discussed below.

- **PDB**

Power distribution board helps to make the connection as well as dispense the rated power from our battery to ESC and flight controller etc. This board also has a couple of switches that can be use to control LEDS, video transmitter power etc.

- **ESC(ELECTRONIC SPEED CONTROLLER)**

ESC is an electronic circuit which can be used to control and prorate power to brushless motor. We have used ESC simonk 30A for high stability crystal oscillator, making the motor control to more precise and efficient.

- **BLDC MOTOR**

Brushless Dc motor is very smooth and tolerances are very tight. It comes with strong C-clip for reliable operation.

- **PROPELLER**

Propeller consists of durable plastic construction which provides lightness, rigidity, good lifting capacity and greater aerodynamic efficiency.

- **FLIGHT CONTROLLER**

Flight controller is the heart of tricopter which direct the RPM of each motor in response to input.

- **SERVO MOTOR**

It used for helping to better torque, capture energy so that the external energy can quickly updated. So we are using MG995 servo motor for controlling the tail yawing.

- **TRANSMITTER AND RECEIVER**

Fly sky FS-i6 [12](fig-5) transmitter is use in the tricopter for automatic hopping digital system (AFHDS) and includes such features as digital trims, backlit LCD screen and simple programming.

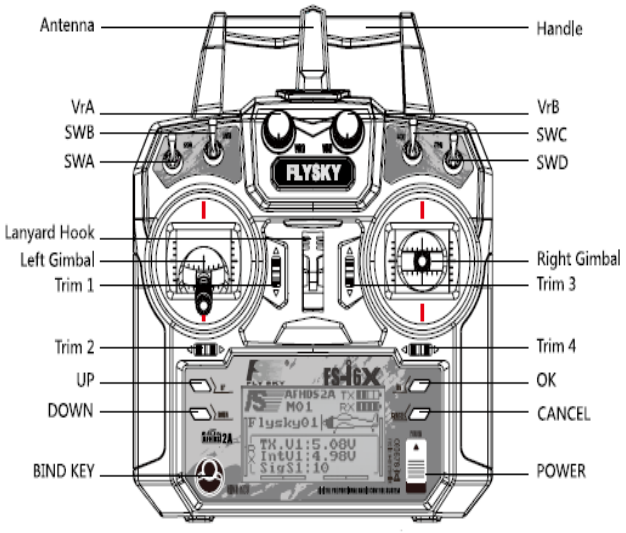


Figure-5: Flight Controller

- **BATTERY**

Battery is the power source of tricopter. We use 3000mah lithium polymer battery for heavy duty discharge leads to minimize resistance and sustain high current loads. This battery is good temperature control and minimum weight.

VI. MATERIALS SELECTION

To make this tricopter we have taken the materials are –

- **Aluminium-**

We use aluminium which is a light metal with a specific weight of 2.7gm/cm^3.

Aluminium is used for making chassis in our project. Because of it is very less weight and cost effective. It also has low density, high conductivity and has an adequate mechanical strength and high corrosion resistance.

- **Wood-**

It is used as a centre plate of tricopter and less weight than other metal. Where centre plate contains PDB, Flight controller, and Battery.

VII. SPECIFICATION OF DIFFERENT COMPONENTS:

SL. NO.	COMPONENTS	SPECIFICATIONS
1	PDB	Mateksys PDB –XT60 I/P voltage :9 to 18 V O/P voltage :5V Burst current : 25A to 12V
2	ESC	SIMONK 30A Dimension :32*24*7 Weight :15gm
3	BLDC MOTOR	RS 2205/2300 KV MOTOR Shaft diameter :5mm Weight :30gm Thrust :1024gm
4	PROPELLER	Size :8*45 Dimension :5
5	FLIGHT CONTROLLER	KK2.1.5 I/P voltage :4.8V to 6.0V Sensors :6050 MCU Weight :26gm
6	SERVO MOTOR	MG 995 servo motor Dimension :40.5*20*44 Weight :55gm

7	TRANSMITTER AND RECEIVER	FLYSKY FS-i6 Weight :392gm, Power :6V,
8	BATTERY	Li- Po battery :3000mah , Weight :292gm O/P voltage :14.8V, Dimension :135*25*45

VIII. HOW WE ASSEMBLE THE COMPONENT

We took a drawing sheet and sketched a tricopter design having a specific dimension. Then an aluminium channel was cut from an aluminium bar with required specific dimension, and then a centre plate design was drawn in the drawing sheet. We made centre plate using wood and than all the parts were assembled using screw and nuts. After that motors, ESC, PDB and flight controller were mounted on the tricopter and wiring was done. We calibrated flight controller according to c.g point balancing and based on that battery was mounted at the base of tricopter.

IX. CALIBRATION

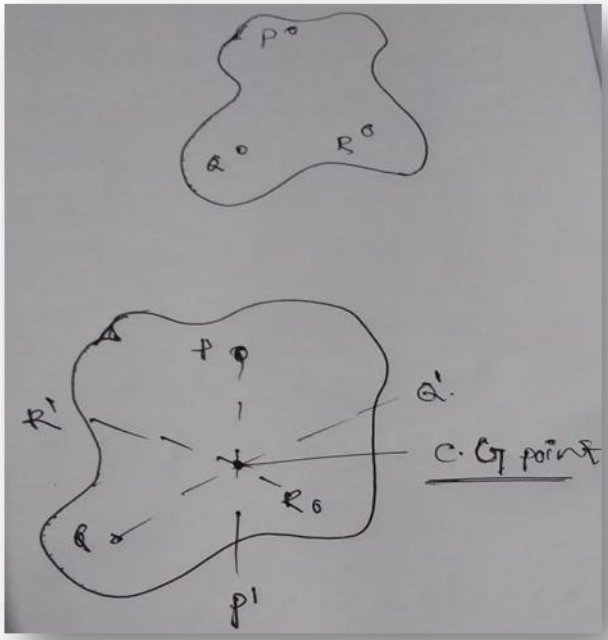
First step- We set the parameter as zero for different function of flight. The functions are aileron, elevator, throttle, and rudder. Then we are fixing the end point value of controller by calibrating the different function of flight. At first receiver was attached to the flight controller. After that power that power was given to the flight controller through ESC. The power supplied to the flight controller is 5 volt. The KK2 display will show error in the first step then after we need to calibrate the flight controller with settings provider by the flight controller manually.

The first step is to calibrate "Receiver test". We calibrated receiver with the transmitter by changing the values. After that we went to "Load motor layout ".According to our copter we chose "Tricopter servo M7" because it gives better stability. According to tricopter motor layout we made the direction of motors. After that we restarted the flight controller. Then we went to "Mixer editor" setting and in mixer editor setting we went to channel 7 and in servo rate setting we changed to high. Then "MPU 6050 setting" was done.

Now "Acceleration calibration" setting we must keep out flight controller in a level surface and we must not touch the flight controller during the process, because it could affect our tricopter stability till it displays "Calibration succeeded". Now we need to check the calibration made is correct or not using "Gyro bubble and ACC bubble" setting. Then "Mode setting" was done. After that we went to "Stick scaling". In this setting we change the value of Yaw (RUD) to 40. Then at last "PI editor" was done based on the motor we used. This setting is important because it shows how our tricopter react on outside wind. Then in display it will show "SAFE". This all setting was done based on the motor we used.

X. EXPERIMENT OF C.G POINT

- The C.G point is must necessary for balancing the tricopter.
- Make 3 hole near the edges of the body so, that the body can swing freely. Let the body hanged at one point and draw a line at "P" and mark the plumbing line "P". Repeat the experiment again Q and R and draw the plumb line Q and R and mark the plumbing line Q and R.
- Now the entire plumb line PP', QQ', and RR' intersect at one point. That point where all the three line meet gives the C.G of body



XI. OBSERVATION

This project focuses on the technological design and infrastructure being used to carry out surveillance along with some new development in this field. We also got our best flight result as stability point of view. In tricopter there is less chances of failure, due to less maintenance. Taking into the consideration the size of tricopter and quadcopter, the lifting capacity of tricopter is more with very low weight. Also the aerodynamic motion is more stable than other .The output of this project can lead the defence system of our country to a respectful and accomplished state. Inaccessible area tricopter help to give the information about the enemy and terrorist activities to our army forces, with the help of camera which are mounted on the tricopter.

The bellow table depict about the different parametric conditions and the stability of tricopter. From the above paragraph it is describe on the different parameter value like aileron, elevator, throttle and rudder which are controlling the flight movement as well as stability. To understand the real time stability of flight we are using gyroscopic sensor and accelerometer .Gyroscope measures angular acceleration in rps on one axis where as accelerometer measures acceleration in one direction .sudden fall or rise of the value give us the unstable condition of flight ,However constant rate of acceleration and angular acceleration describe the stability.

The flight parameters are in percentage and control by using FLY SKY Fi6 flight controller . We get the value of gyroscopic condition with the help of a arduino board and GY-521MPU 3 axis gyroscope module .

EX NO	Aileron	Elevator	Throttle	Ruder	Gyroscope condition
1	70	55	10	80	Unstable
2	100	70	10	80	Stable
3	70	55	50	80	Stable
4	100	70	50	80	Unstable
5	70	55	80	80	Stable
6	70	55	90	80	Unstable
7	70	55	100	80	Unstable

Table-2: Flight Movement condition

XII. CONCLUSION

In this report of the project that we carried out we have tried to bring out the Mathematical Model of the tricopter and derived the Translational and Rotational equations for the Tricopter as well as solid works simulation to predict the position of the tricopter during flight. We have successfully completed first part of our project i.e. –tricopter. We have made a prototype of tricopter .We have also tested and made a trial flight in a field. We have made stable C.G point i.e. - tricopter is very stable in air.

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