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PROBLEMS ASSOCIATED WITH THE STABILITY OF BICOPTERS AND TRICOPTERS

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Abstract

This research work begins with the definition of cyclorotor and aero amphibious vehicles. The superimposition of vortex flow with non-lifting flow over a cylinder being discussed to show that such theoretical concepts could have practical application. The Design portion mentioned in this manuscript deals with every design aspect from the dimensions to the various Dynamic forces acting on the Aeroamphibious Cyclorotor body. Motor directions with high or low logic puts this manuscript to a programming domain, still the extensive calculations involved with the lift and drag equations for each rotor blades and the overall lift with motor RPM brings it to a descent aerodynamic domain. The extensive calculations involve in this research work includes both aerial conditions as well as aquatic conditions.

1. INTRODUCTION

Bi copters and Tri copters are not that famous that of quadcopter and Hexa copters, but still, it always fantasizes the drone enthusiast due to the way it works. Most of the drone hobby is generally don't build bi copters and tri copters due to its less pay load capacity and difficulty to control.

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Still for the control system enthusiasts, the bicopter and tricopter are one of the major interest. The oscillations those are produced in the bicopter and tricopter are very difficult to arrest. To successfully arrest and make them stable, usage of flight controllers is of major concern. The bicopter and tricopter tested for producing this manuscript was KK2.1.5 flight controller. It comes with cheap price than the other flight controllers and has wide range of drone configurations in it.

The concept and design for the bicopter and the tricopter is bit more complex than the quadcopter and hex copter which has been explained here. One can use this design and concept described in this manuscript and make a successful bicopter and tricopter.

2. LITERATURE REVIEW

Esa Apriaskar et al (2019) presented a study on the bicopter using Zieglar-Nicholas based PID controllers. He plotted the graph of the root locus plot for the balancing bicopter system. He has compared the data of P Controller, PI controller and PID controller by using Zieglar Nicholas rule and compared the performance among these three controllers. The result shows the parameter value of Kp in P controller showing transient response. So P controller is not suitable because of its steady state error. The comparison between PI controller and PID controller shows that, PI is giving better performance than PID as it is giving drawbacks despite of having good performance in rise time.[1]

Lukáš Hrečko et al (2015) presented a study of Bicopter stabilization based on IMU sensors. Here he explained about the construction of laboratory model Bicopter and some issues in its stabilization that he faced during flight. He also shows the respective control loop design and signal measurement processing. Result shows that, it is working according to expectation and performance is up to the mark. But some issues are still there while controlling pitch axis. He also mentioned that, in this case the control process shows slight angle error while swift air manueuvers [2]

Stephen Carlson et al (2014) gave a detailed explanation about A Hybrid Tricopter / Flying VTOL UAV .Here he tried to potray that, the vehicle design will be accessed for modification. The vehicle is featured by standardize mounting hole grid pattern for further modification. In his study he also mentioned about planform and rotor configuration, motor and propeller selection, wing geometry and airfoil selections and other design optimizing. PID controller topology, flight controller software architecture and video telemetry electronics are described. [3]

Anna Prach and Erdal Kayacan et al (2017) demonstrated about An MPC-based position controller for a tilt-rotor tricopter VTOL UAV. They shows the fusion of conventional controller and linear predictive controller for the position control of a tilt rotor tricopter. Here they potrays that the proposed controller has multi loop structure that comprises a conventional PID Control method and linear MPC. Since MPC is based on a linear prediction model so that problem will be there and it should be solved offline by reducing the computational power requirements. But he says the proposed approach has a large potential for real time applications where computational power is restricted. One of the challenges they mentioned during MPC design is the formulation of the input constraints

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due to the absence of a one-to-one mapping between the direct control inputs and MPC inputs. In this work, they implement approximate input constraints, while the actuator limitations are taken into account in the simulation mode.[4]

3. DESIGN

Bicopter Mechanism:

Bicopter drones are though not used widely for most the applications, still it has its place for research, especially in drones.

The bicopter used were using the KK2.1.5 flight controller. The bicopter need 2 metal servo motors for the tilting of thrusters.

For roll operations, the bicopter need to work in such a way that, one motor should have more RPM than the other. That is, if the bicopter has to roll right from the pilot's view, the right-side thruster should have less RPM than the left side thruster. If the bicopter to roll left from the pilot's view, the left side thruster should have more RPM than right-side thruster.

For pitch operations, the bicopter need to work in such a way that, both motors should have same RPM but tilted in the direction drone has to move. That is if the bicopter has to pitch forward from the pilot's view, both the thrusters should tilt forward with same RPM. If we increase or decrease the RPM, drone accelerates or decelerates in forward direction. If the bicopter has to pitch backward from the pilot's view, both the thrusters should tilt backward with same RPM. If we increase or decrease the RPM, drone accelerates or decelerates in backward direction.

For yaw operations, the bicopter need to work in such a way that, one motor should tilt forward and the other thruster should tilt backward. If the bicopter has to yaw left from the pilot's view, the right thruster should tilt forward and the left thruster should tilt backward. If the bicopter has to yaw right from the pilot's view the right thruster should tilt backward and left thruster should tilt forward.

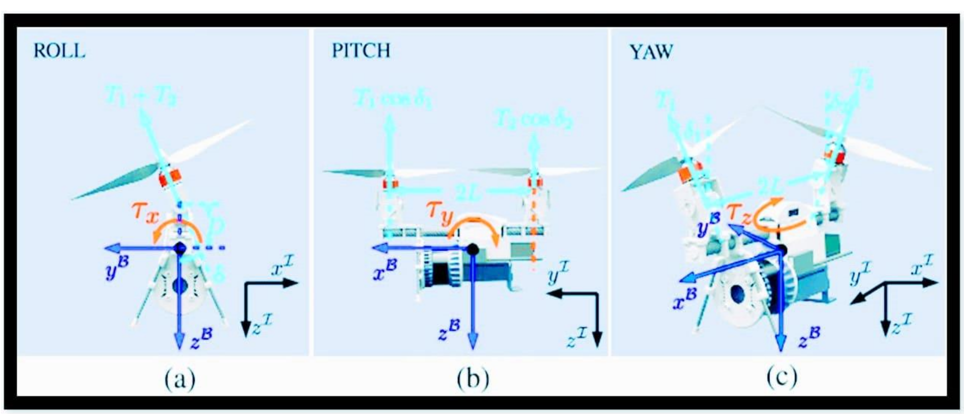

Figure 1: Bicopter Mechanism for Roll, Pitch and Yaw operations.

[5]

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Tricopter Mechanism:

Rotor 1 is tail rotor which has the capacity to tilt right or left. Rotor 1 is made to rotate clock wise.

Rotor 2 and 3 are placed forward from the center of gravity. Rotor 2 is made to rotate clockwise and Rotor 3 is made to rotate counterclockwise

To perform hover all three rotors, have to rotate in same speed. If the drone has to increase its altitude, then RPM of all three rotors has to be increased. If the drone has to decrease its altitude, then RPM of all three rotors has to be decrease. This control is called Altitude Control.

To perform Roll Rotor 2 and Rotor 3 has to vary their RPM according to the direction of roll. For counterclockwise Roll, the Rotor 3 should have increased RPM and the Rotor 2 should have deceased RPM. For clockwise Roll, the Rotor 3 should have decreased RPM and the Rotor 2 should have increased RPM. This control is called roll control.

To perform pitch, the Rotor 1 has to increase or decrease the RPM according to the direction of pitch. For nose up condition the Rotor 1 has to decrease RPM then Rotor 2 and Rotor 3. For nose down condition the Rotor 1 has to increase the RPM than Rotor 2 and Rotor 3. This control is called Pitch Control.

To perform Yaw, the Rotor 1 has to tilt right or left according to the direction of yaw. For counterclockwise yaw, the Rotor 1 has to tilt right keeping Rotor 2 and Rotor 3 unchanged. For clockwise yaw the Rotor 1 has to tilt left keeping Rotor 2 and Rotor 3 unchanged. This control is called Yaw Control.

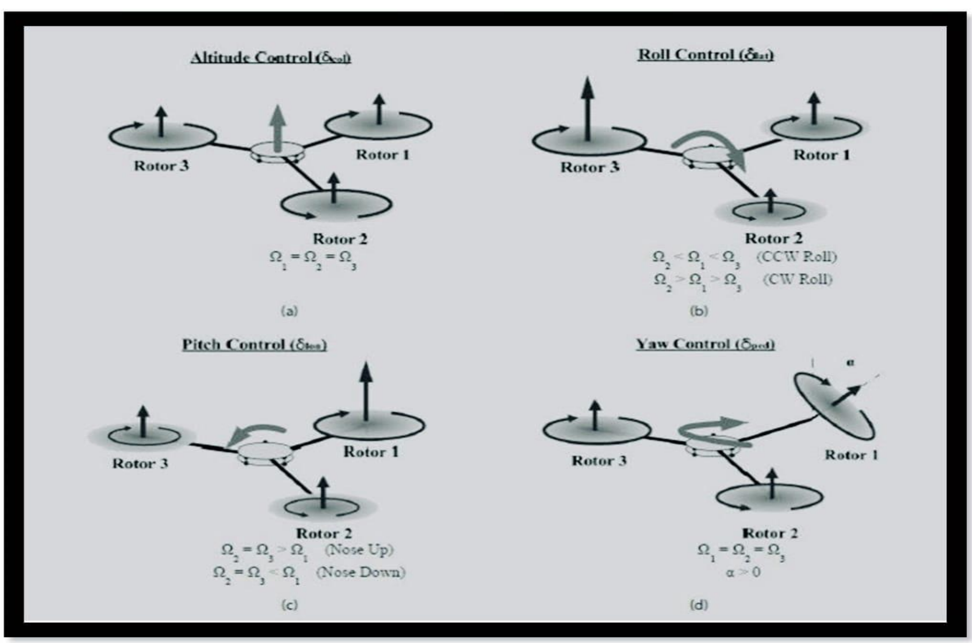

Figure 2: Tricopter Mechanism for Roll, Pitch and Yaw mechanisms [6]

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Position of thrusters:

The position of thrusters is chosen in such a way that the center of gravity is not supposed to move forward or backward and kept remain unchanged. The position of the thrusters is in the same line where center of gravity acts, but adjacent to center of gravity. This helps to lift the drone from center of gravity. The position of thrusters is kept in such a way that the pitch moment, the roll moment, and the yaw moment, all will act in a single point that is center of gravity.

If both the Rotors rotate in high RPM then drone will move vertically upward. If both the rotors rotate in less RPM then drone will move vertically downward direction. The motion is produced in such a way that the forces are acting equally about the center of gravity which indeed doesn’t produce any unwanted moments and thereby make the drone stable.

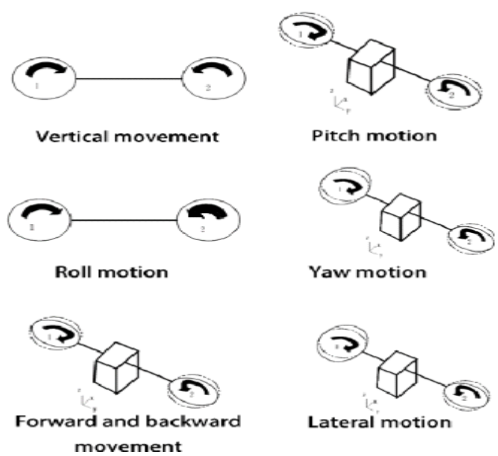

Figure 3: Bicopter thruster position [7]

In pitch motion, the thruster’s tilt mechanism produces the lateral motion that is aligned with center of gravity. The pitch forward requires the thruster’s tilt motion forward. The tilt would produce the force in a certain angle such that the force component can be resolved. The vertical component will take care of the lift force and the horizontal component will take care of the forward force. The RPM of the thruster makes the drone accelerate or decelerate. The pitch backward requires the thruster’s tilt motion backward. The tilt would produce the force in a certain angle such that the force component can be resolved. The vertical component will take care of the lift force and the horizontal component will take care of the backward force. The RPM of the thruster makes the drone accelerate or decelerate.

In roll motion, the thruster’s differential RPM produces moment about centre of gravity. The right thruster should have more RPM than the left thruster to provide the moment about the centre of gravity. As the force from the right thruster is more than the left thruster, and the thrusters are being located at some distance from the centre of gravity that extra force multiplied with that distance would produce a moment which called rolling moment. This moment makes the bicopter roll left. The left thruster should have more RPM than the right thruster to provide the moment about the centre of gravity. As the

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force from the left thruster is more than the right thruster, and the thrusters are being located at some distance from the centre of gravity, which extra force multiplied with that distance would produce a moment which called rolling moment. This moment makes the bicopter roll right.

In yaw motion, the thruster's tilt mechanism in opposite manner produces yawing moment about centre of gravity

Table I. Various Propulsive Movements of Bicopter

	Throttle		Pitch		Yaw		Roll	
	Up	**Down**	**Forward**	**Backward**	**Left**	**Right**	**Left**	**Right**
Left Motor	↑	↓	Front thrust	Back thrust	Back thrust	Front thrust	↓	↑
Right Motor	↑	↓	Front thrust	Back thrust	Front thrust	Back thrust	↑	↓

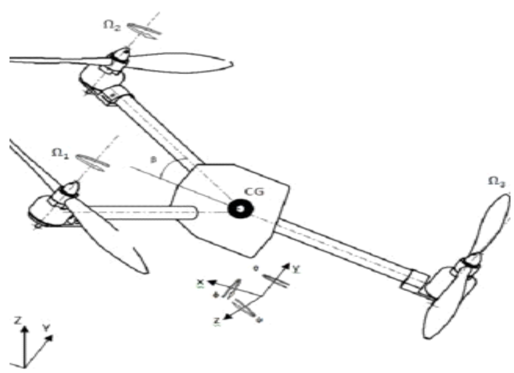

Figure 4: Tricopter thruster position [8]

Table II. Various Propulsive Movements of Tri Copter

	Throttle		Pitch		Roll		Yaw	
	Up	**Down**	**Forward**	**Backward**	**Left**	**Right**	**Left**	**Right**
M1	↑	↓	↑	↓	No change	No change	Tilt right	Tilt left
M2	↑	↓	↓	↑	↓	↑	No change	No change
M3	↑	↓	↓	↑	↑	↓	No change	No change

Challenges faced during fabrication of Bicopter and Tricopter:

Bicopter fabrication:

We tried to make the hinges with wooden planks. In this bicopter we kept black colour metal servo motor and we used aluminium L shape piece to attach one side to the servo motor and other end we attached BLDC motor. To maintain centre of gravity we kept battery, flight controller we kept in the middle.

The Bicopter has two motors and two servos. The two motors rotate with the help of servos. Controls are normally achieved through differential thrust vectoring achieved by tilting the prop-rotors in calculated directions. The propellers on a bi-copter rotate in the opposite direction. These propeller pairs will create lifting thrust without rotating in the same direction. Each rotor generates power and torque along its axis of rotation, as well as a drag force in the opposite direction of the vehicle's flight path. The net aerodynamic

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torque, and the angular acceleration along the yaw axis, are exactly zero if all rotors spin at the same angular velocity.

Figure 5: Bicopter Aluminium Frame

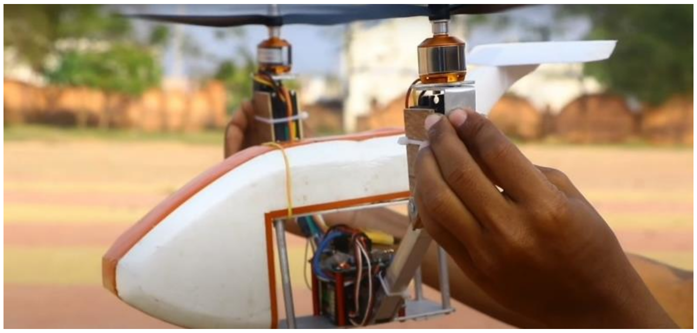

Figure 6: Bicopter Tilting Mechanism

A microcontroller (MCU for microcontroller unit, or UC for controller) is a small computer on a single integrated circuit. In modern terminology, it is similar to, but less sophisticated than, a system on a chip or SoC; a SoC may include a microcontroller as one of its components. The LCD screen and built in software makes install and setup easier than ever. A host of multi-rotor craft types are pre-installed, simply select your craft type, check motor layout/propeller direction, and calibrate your ESCs and radio, which is done on screen prompts. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general-purpose applications consisting of various discrete chips.

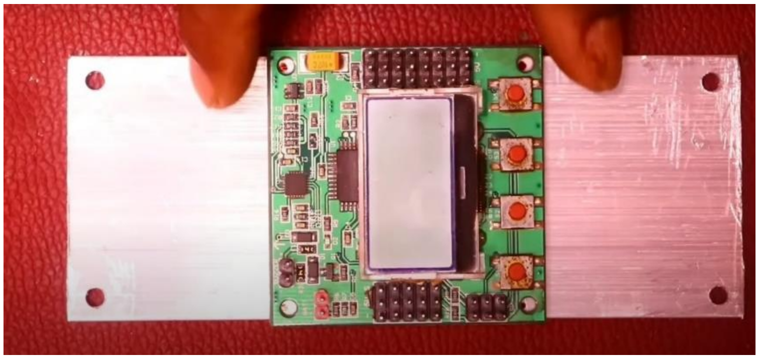

Figure 7: KK2.1.5 flight controller

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Tricopter fabrication:

We tried to make landing gear of tricopter with wooden plank to maintain centre of gravity we kept battery, flight controller in the middle of the drone. In this tricopter drone 3rd motor is tilt rotor it is helpful in yaw moment.

We tried to make landing gear of tricopter with wooden plank to maintain centre of gravity we kept battery, flight controller in the middle of the drone. In this tricopter drone 3rd motor is tilt rotor it is helpful in yaw moment. We can see in the figure below

Figure 8: Tricopter rear motor with tilt function

The third thruster in the tricopter has tilt mechanism to provide anti torque effect and thereby controlling the yawing motion. The thruster in the above diagram shows the way the motor tilt and balances the forces in the upward motion and the moment produced for the yaw motion.

Tri copter is an aircraft which works with 3 propelling blades to generate lift and tilts its body to achieve required motion. A tricopter has two clockwise or counter clock wise rotating propellers to which the 3rd propeller is to be opposite in direction. A tricopter is stable because of this simple tail mechanism that uses it to adjust the rotation and yaw the aircraft. The Stability in air is also tightly maintained by a flight controller. A tricopter has 2 rotors spinning in opposite directions but the third rotor produces anti torque that tries to spin the tricopter. The rear servo was used to tilt the rear rotor to compensate this torque in the same manner a helicopter tail rotor does.

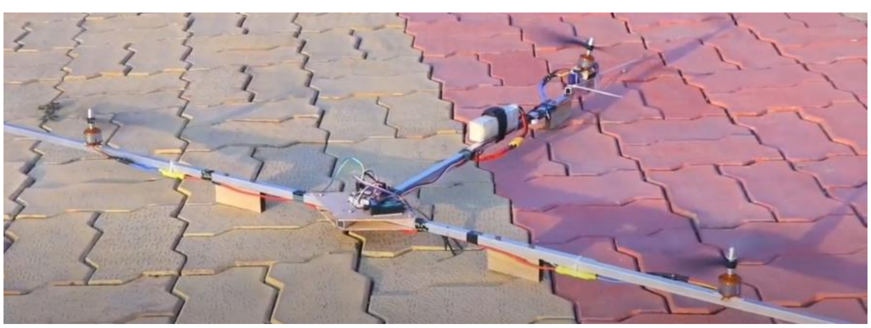

Figure 9: Tricopter

4. RESULTS AND DISCUSSION:

The bicopter was producing a little unwanted moment that made the thrusters oscillate about the centre of gravity. The flight controller used was KK2.1.5 and was not giving the satisfying results for the bicopter. Though the bicopter was oscillating, it was in the air that show the motor and propeller choice made necessary lift. But controlling was difficult.

The tricopter was producing the unwanted moments in yaw axis. The flight controller was not giving satisfying results in yaw motions though. The Tricopter took off and was flying in the air, which shows the motor and propeller choice made necessary lift. But again, the controlling was difficult.

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