International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

Design, Analysis & Fabrication of RC Hybrid Drone

B Manu
Of Department of Mechanical Engineering
Bangalore Institute of Technology
Bengaluru, India

Chetan H N
Of Department of Mechanical Engineering
Bangalore Institute of Technology
Bengaluru, India

Ankit Kumar
Of Department of Mechanical Engineering
Bangalore Institute of Technology
Bengaluru, India

Dr. Nagaraja C Reddy
Associate Professor
Of Department of Mechanical Engineering
Bangalore Institute of Technology
Bengaluru, India

Jeevana Gowda B P
Of Department of Mechanical Engineering
Bangalore Institute of Technology
Bengaluru, India

***Abstract*—This paper presents the MAC-J drone, a novel concept of unmanned hybrid vehicle for both aerial and underwater applications. The best architecture for this kind of vehicle was evaluated based on the adaptation of typical platforms for aerial and underwater vehicles, to allow the navigation in both environments. The model selected was based on a quadrotor-like aerial platform, adapted to dive and move underwater. Here, we discuss the respective control laws used to stabilize the system in the air and under the water. Similar to other air/water vehicles in the literature, our robot can also navigate in both environments without mechanical adaptation during the medium transitions. Finally, we conclude the paper by highlighting some of the current research trends in this area.**

I. Introduction

In the last few years, unmanned autonomous vehicles have been the focus of many development efforts, with a large range of applications. Both kind of vehicles are well adapted to work in their own environment (air and water, respectively), but some situations may require a single vehicle capable of working in both environments. Such requirement commonly appears when is necessary to perform maintenance on partially or fully submersing structures, as ship hull. The interest in new hybrid systems for aerial and underwater exploration has greatly increased. This kind of vehicle presents many interesting applications like the mapping problem in rain forests or polar regions, or search and rescue in flooded areas. Such environments are challenging for robots due to the requirement for transit between air and water media to obtain a full perception.

Untethered hybrid drones are more versatile and can be used for a wider range of application. They operate autonomously and do not require a physical connection to a power source or data transfer line. These drones are commonly used for search and rescue, marine life observation and environmental monitoring. Here we propose a novel, efficient and cheaper design for robots capable of navigating in both, air and water, environments. Our proposed platform keeps many advantages of multirotor, such as hovering and miniaturization. Similarly, to other *quadrotor-like projects* in the literature, our robot quickly transits between aerial and aquatic media, without the necessity of mechanical changes in its structure, and acts as a normal drone when performing flying missions.

This paper is structured as follows: related works are presented in Section II; Section III provides the methodology used in the design of our vehicle; simulated experiments are presented in Section IV; and finally, in Section V, we conclude and discuss avenues for future investigation.

II. Design & Constructon

A. Design considerations

The design of a hybrid drone requires careful consideration of the following components:

1. *Propulsion system*: Hybrid drones require two propulsion systems, one for flying and the other for underwater. The flying propulsion system typically consists of rotors or propellers, while the underwater propulsion may be thrusters or fins.
2. *Waterproof design*: Hybrid drones must have a waterproof design to protect the internal components while operating underwater. The drone's body should be designed to be watertight, and the components should be designed to be watertight, and the components should be protected from water damage.
3. *Buoyancy control*: Hybrid drones require a system that can control their buoyancy to maintain the desired depth while underwater. This system can be achieved using ballast tanks.
4. *Cameras and sensors*: Hybrid drones require cameras and sensors to capture aerial and underwater footage, perform inspections and collect data. The cameras and sensors should be designed to withstand the harsh environments encountered in both air and water.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

B. Construction of a Hybrid drone

The construction of a hybrid drone involves the following steps:

1. *Frame construction*: The frame is the backbone of the drone, and it should be designed to accommodate the components required for both aerial and underwater operations. The frame should be sturdy and light weight to allow the drone to maneuver efficiently in both environments.
2. *Waterproofing*: The drone's body should be designed to be watertight to prevent water from entering the internal components. The waterproofing can be achieved using a combination of seals, gaskets and adhesives.
3. *Buoyancy control*: The buoyancy control system can be achieved using ballast tanks. The ballast tank can be filled with water to increase the drone's weight and cause it to sink.
4. *Cameras and sensors*: The cameras and sensors should be designed to withstand the harsh environments encountered in both air and water. The camera should be able to capture high-quality footage in low-light conditions, while the sensor should be able to collect data accurately.

III. IDEOLOGY

A. Methodology

The methodology used in the development of a MAC-J drone involves the following steps:

1. *Conceptualization*: The first step in developing a hybrid aerial and underwater drone is to conceptualize the design and functionality of the drone. This involves defining the requirements, identifying the challenges, and establishing the goals for the drone.
2. *Design*: Once the concept has been established, the design process begins. This involves creating a detailed 3D model of the drone, selecting the materials and components, and developing the propulsion and control systems for both aerial and underwater operation.
3. *Prototype Development*: With the design in place, a prototype of the drone is developed. The prototype is typically a scaled-down version of the final product and is used to evaluate the functionality and performance of the drone in both aerial and underwater environments.
4. *Testing and Evaluation*: The next step is to test and evaluate the prototype in real-world conditions. This involves testing the drone in different environments, such as in water and in the air, to ensure that it performs as intended.
5. *Refinement*: Based on the results of the testing and evaluation, the drone design is refined to improve its performance, reliability, and functionality. This may involve modifications to the propulsion and control systems, as well as changes to the materials and components used in the drone.
6. *Production*: Once the drone design has been refined and optimized, the final product is produced. This involves manufacturing the drone components, assembling the drone, and testing the final product to ensure that it meets the required specifications.

B. MAC-J drone electronics

The electronics used in a MAC-J drone includes:

1. A KK2.1.5 controller is used to control multirotor RC models. It consists of a microcontroller and an inertial measurement unit(IMU).
2. A high frequency, Futaba FSi6, RC transmitter, and receiver is used to communicate with the MAC-J underwater.
3. A water pump speed controller, is used to control the ballast system.
4. Four brushless DC motors are used along with the ECSs which are used to control the motors.
5. Arduino UNO is used to control the sensors such as ultrasonic sensor, temperature sensor etc. and to get the output.
6. Two pair of carbon fiber propellers are used to generate thrust.

C. Equations

There are many different formulas and equations that can be used in the design of a hybrid aerial and underwater drone, depending on the specific parameters and requirements of the drone. Here are some of the key formulas and equations that are relevant to the design of a hybrid drone:

1. *Lift and Drag*: The lift and drag forces acting on the drone's wings or rotors can be calculated using equations such as the lift equation

$$L = \frac{\rho v^2 A C_l}{2} \quad (1)$$

and the drag equation

$$D = \frac{\rho v^2 A C_d}{2} \quad (2)$$

L is lift force, ρ is air density, v is velocity, A is wing or rotor area, C_l is lift coefficient, and C_d is drag coefficient.

2. *Propulsion*: The thrust generated by a propeller or motor can be calculated using equations such as the basic thrust equation

$$T = \rho A V^2 C_p \quad (3)$$

T is thrust force, ρ is fluid density, A is propeller or motor area, V is velocity, and C_p is the power coefficient.

3. *Stability and Control*: The stability and control of the drone can be analysed using equations such as the moment equation

$$M = I\alpha \quad (4)$$

M is moment, I is moment of inertia, and α is angular acceleration.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

4. *Battery Capacity*: The battery capacity required to power the drone's various components can be calculated using equations such as the energy equation

$$E = Pt \quad (5)$$

E is energy, P is power, and t is time.

5. *Buoyancy*: The buoyancy of the drone in water can be calculated using the buoyancy equation:

$$B = \rho_f V_d g \quad (6)$$

B is buoyancy force, ρ_f is fluid density, V_d is volume of fluid displaced, and g is acceleration due to gravity.

D. Ballast system

A vital component of underwater drones is the ballast system, which enables the drone to control its buoyancy and depth while submerged. The ballast system is essential for the drone's stability, maneuverability, and safety while operating underwater.

The ballast system of an underwater drone typically consists of a ballast tank, pumps, and valves. The ballast tank is a water-tight container that can be filled with water to increase the weight and make the drone more negatively buoyant, or emptied to decrease the weight and make the drone more positively buoyant.

The pumps are used to transfer water in and out of the ballast tank. There are different types of pumps that can be used, such as centrifugal pumps or piston pumps, depending on the size and design of the drone. The valves control the flow of water between the ballast tank and the outside environment, allowing the drone to adjust its buoyancy and depth.

The ballast system is typically controlled by a computer or other control system, which monitors the drone's depth and adjusts the ballast system accordingly. The control system can also take into account other factors, such as the drone's speed, orientation, and environmental conditions, to maintain stable operation.

In addition to the basic ballast system, there are other features that can be added to underwater drones to enhance their performance and capabilities. Overall, the ballast system is a critical component of an underwater drone, allowing it to adjust its buoyancy and depth to navigate the underwater environment effectively. By using advanced control systems and innovative materials, designers can continue to improve the performance and capabilities of underwater drones for a variety of applications.

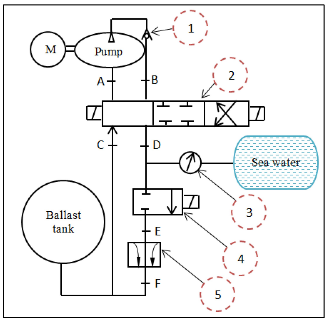

Fig.1. *Structure of a basis ballast system*

IV. CENTER OF BUOYANCY AND CENTER OF GRAVITY CONTROL

The center of buoyancy and the center of gravity are two important factors that need to be considered in the design and control of a hybrid drone.

The center of buoyancy is the point where the upward force of the water on the drone is applied. It is the centroid of the volume of water displaced by the drone. The center of gravity, on the other hand, is the point where the weight of the drone is concentrated. It is the point where the drone would balance if it were suspended from a string.

In a hybrid drone, the position of the center of buoyancy and the center of gravity can affect the drone's stability and control. If the center of buoyancy is too far forward, the drone will pitch up, and if it is too far back, the drone will pitch down. If the center of gravity is too far forward, the drone will be unstable, and if it is too far back, the drone will be too sluggish.

To control the position of the center of buoyancy and the center of gravity in a hybrid drone, we used ballast systems. For example, the fuel tank can be placed in various locations to shift the center of gravity forward or back. Similarly, the location of the batteries and motors can be adjusted to shift the center of buoyancy.

Once the drone is built, its flight controller can be programmed to adjust the position of the center of gravity and center of buoyancy dynamically. This can be done using sensors that detect the drone's orientation and adjust the position of components to maintain stability and control.

Overall, controlling the position of the center of gravity and center of buoyancy is an important part of designing and operating a hybrid drone. By carefully balancing the weight and buoyancy of the drone, designers can ensure that it is stable, efficient, and easy to control in a variety of flight conditions.

V. ATTITUDE CONTROL AND STABILITY

Attitude control and stability are critical factors in the design and operation of a hybrid drone. Attitude refers to the orientation of the drone, including its pitch, roll, and yaw. Stability refers to the drone's ability to maintain its attitude and resist disturbances from wind, turbulence, or other external factors.

To achieve attitude control and stability in a hybrid drone, several design and control strategies can be employed:

1. *Aerodynamic design*: The aerodynamic design of the drone can be optimized to ensure stable flight. The drone's wings, rotors, and other components should be designed to minimize turbulence and provide maximum lift.
2. *Flight control system*: The drone's flight control system can use sensors to detect its orientation and make adjustments to maintain stability. This can be achieved using a combination of gyros,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

accelerometers, and other sensors that detect changes in the drone's position and speed.

3. *Autopilot*: An autopilot system can be used to automate the drone's flight and maintain stable flight. The autopilot can use input from sensors to adjust the drone's attitude and altitude to maintain a stable flight path.
4. *Feedback control*: Feedback control can be used to adjust the drone's attitude in response to changes in its flight conditions. This can be achieved by using sensors to detect changes in the drone's orientation and adjusting its flight path in real-time.
5. *Propulsion control*: The drone's propulsion system can be controlled to adjust its attitude and maintain stability. For example, the pitch and roll of the drone can be adjusted by changing the speed of the rotors on one side of the drone.

Overall, achieving attitude control and stability in a hybrid drone requires careful design and control. By optimizing the aerodynamic design of the drone, using sensors and feedback control to maintain stability, and adjusting the drone's propulsion system, designers can ensure that the drone is capable of stable and controlled flight in a variety of conditions.

V. *Design and analysis*

Fig.2. *Sample CAD model of the proposed MAC-J drone*

TABLE I. STRESS ANALYSIS

Stress	Min.	Max.
Von Mises	9.067E-07 MPa	0.02625 MPa
1st Principal	-0.01304 MPa	0.03512 MPa
3rd Principal	-0.02916 MPa	0.01019 MPa
Normal XX	-0.02315 MPa	0.02332 MPa
Normal YY	-0.02175 MPa	0.02759 MPa
Normal ZZ	-0.01549 MPa	0.01682 MPa
Shear XY	-0.01024 MPa	0.01059 MPa
Shear YZ	-0.01148 MPa	0.01025 MPa
Shear ZX	-0.01262 MPa	0.01267 MPa

[a] *Stress Analysis of prototype MAC-J drone.*

TABLE II. STRAIN ANALYSIS

Strain	Min.	Max.
Equivalent	6.218E-10	2.283E-05
1st Principal	-2.186E-07	2.414E-05
3rd Principal	-2.103E-05	-3.959E-10
Normal XX	-8.104E-06	9.294E-06
Normal YY	-7.273E-06	9.358E-06
Normal ZZ	-5.211E-06	5.548E-06
Shear XY	-1.488E-05	1.538E-05
Shear YZ	-1.668E-05	1.489E-05
Shear ZX	-1.834E-05	1.841E-05

[b] *Strain analysis of prototype MAC-J drone.*

ACKNOWLEDGMENT

We would like to thank our Head of the Department, Dr. T V SREERAMA REDDY and our guide Dr. NAGARAJA C REDDY and special thanks to Dr. E R BABU for their valuable advice and technical assistance.

REFERENCES

[1] Hamzeh Alzu'bi, Iyad Mansour, and Osamah Rawashdeh, Implementation of a hybrid unmanned aquatic-aerial quadcopter with active buoyancy control.

[2] Drews, P., Neto, A., & Campos, M. (2009, May). A Survey on Aerial Submersible Vehicles. IEEE/OES Oceans International Conference, Bremen, Germany.

[3] Drews, P., Neto, A., & Campos, M. (2014, September). Hybrid Unmanned Aerial Underwater Vehicle: Modeling and Simulation. Paper presented at the IEEE/RSJ International Conference on Intelligent Robots and Systems, Chicago, USA.

[4] Fabian, A., Feng, Y., Swartz, E., Thurmer, D., & Wang R., (2012). Hybrid aerial underwater vehicle (MIT Lincoln Lab). SCOPE Projects. From : http://www.olin.edu/collaborate/scope/projects/2011_12/mit_ll

[5] Tan, Y., Siddall, R., & Kovac, M. (2017). Efficient Aerial–Aquatic Locomotion with a Single Propulsion System. IEEE Robotics and Automation Letters, 2(3), 1304–1311.

[6] Yang, X., Wang, T., Liang, J., Yao, G., & Liu, M. (2015). Survey on the novel hybrid aquatic– aerial amphibious aircraft: Aquatic unmanned aerial vehicle (Aqua UAV). Progress in Aerospace Sciences, 74, 131–151.

[7] Hopkins University Applied Physics Laboratory. (2016, March 17). New UAV Can Launch from Underwater for Aerial Missions [Press release]. From: http://www.jhuapl.edu/newscenter/pressreleases/2016/160317.as