

Unmanned Vehicle with Mobility on Land, Water and Air

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Abstract

Unmanned vehicles are becoming a crucial tool for many military operations. High risk missions like encounter operations and surveillance demands the need for advanced multi-purpose vehicles that can negotiate and achieve the goals. The present classes of unmanned vehicles include ground vehicles, aerial vehicle and water vehicle which are limited to one or two mode of operations. During a situation when the vehicle has to move through land, air and water, a single unit of present vehicles will not satisfy the need. This project suggests a solution for this problem by designing and fabricating a radio controlled unmanned vehicle with three modes of mobility. The vehicle is named Dragon and is aimed to attain three modes of mobility. The design process started with analysing the requirements and building up the design concept by testing on a prototype. The final design was made in Solidworks design software. Then the vehicle was fabricated, tested and was successfully operated. The project was able to provide an innovative solution and inspiration for a new class of unmanned vehicles.

Keywords: *Unmanned Vehicles (UVs), Dragon, Solidworks*

I. INTRODUCTION

The name of Unmanned Vehicles (UVs) or Unmanned Systems (USs) covers all vehicles operating in air, ground, water and combination of them with no person on board the system with a capability controlling the vehicle. The research on an unmanned vehicle has been on going during the last decades. The term of an unmanned vehicle as defined by Association for unmanned vehicle systems international (AUVSI), which might also be called robotic service vehicles, are in three broad categories: first is unmanned aerial vehicle (UAV's) as airborne type, second is the ground-based vehicle (UGV), and third is water-based vehicle which include surface craft (USV's) and underwater vehicle (UUV's).

All the unmanned vehicle kinds have many common purposes. They are used in both civilian and military needs, such as exploration and inspection, search and rescue, surveillance, traffic management and for recreational and entertainment purposes.

II. PROPOSED DESIGN & CALCULATIONS

Various design features of the existing unmanned vehicles were considered while looking for an effective configuration that enables three modes of mobility. After many sketches and design reviews a final design was fixed. A CAD drawing was made in Solidworks software for the final design of the vehicle. This is shown in the figure.

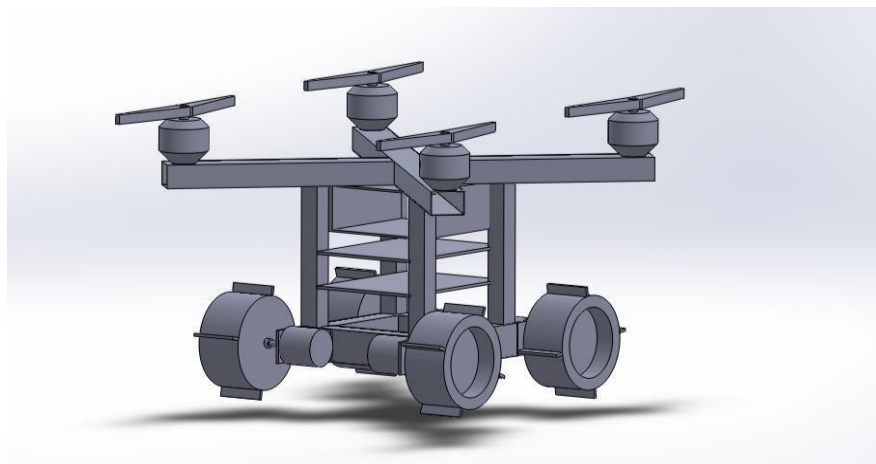


Fig. 1: CAD drawing of the vehicle drawn in Solidworks

The configurations of an unmanned ground vehicle and a quadcopter were blended to achieve mobility on land and air. The wheels and frame of the vehicle were designed to be hollow for floating on water.

Material Selection:

Aluminium was chosen for building the frame of the vehicle since it is light weight. Materials chosen for the body are foam, Hylum and plastic. The wheels were planned to be handcrafted and to be made with plastic and foam.

DESIGN CALCULATIONS

In order to roll on a horizontal surface, the motors of the vehicle should produce

enough torque to overcome any imperfections in the surface of wheels as well as friction in the motor itself. Therefore theoretically the vehicle does not require much torque to move purely horizontally.

In order for a robot to roll up an inclination at a constant velocity, it must produce enough torque to counteract the effect of gravity which would otherwise cause it to roll down the inclination. In an inclined surface only one component of the weight causes the robot to move downwards. The other component is balanced by the normal force the vehicle exerts on the wheels.

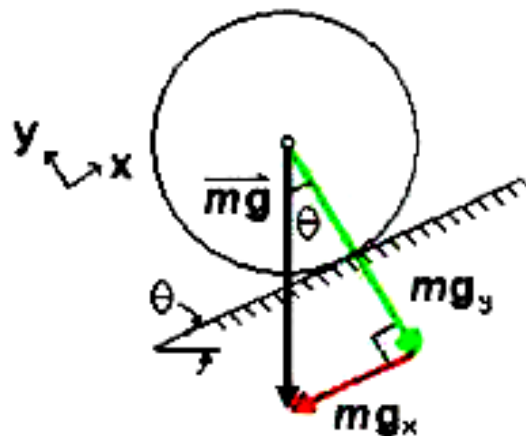


Figure: 2

$$mg_x = mg \sin \theta$$

$$mg_y = mg \cos \theta$$

The torque, $T = f * R$

On inclined plane and accelerating up,

$$\sum F_x = m * a = f - mg_x$$

Substituting equation of torque and mg_x to the above equation,

$$m * a = \frac{T}{R} - mg \sin \theta$$

$$\begin{aligned} T &= R * m * (a + g \sin \theta) \quad \text{where } m=2.3 \text{ kg, } R=0.05\text{m, } a=0.2\text{m/s}^2 \\ &= 0.05 * 2.3 * (0.2 + 9.81 \sin 40) \\ &= 0.748 \text{ Nm} \end{aligned}$$

$$\begin{aligned} \text{For each motor, Torque } T &= \frac{\text{Total Torque}}{4} \\ &= \frac{0.748}{4} = 0.187 \text{ Nm} \end{aligned}$$

Considering efficiency is 80%

$$T = \frac{100}{80} * 0.187 = 0.23375 \text{ Nm}$$

$$\text{Power, } P = T * \omega$$

$$\text{Velocity, } V = R * \omega$$

Assuming Velocity of vehicle to be 0.5 m/s

$$\omega = \frac{V}{R} = \frac{0.5}{0.05} = 10 \text{ rad s}^{-1}$$

$$\text{Also } \omega = \frac{2\pi N}{60},$$

$$N = \frac{\omega * 60}{2\pi} = \frac{10 * 60}{2 * 3.14} = 95.54 \text{ rpm}$$

$$\begin{aligned} \text{Power, } P &= \frac{2\pi NT}{60} \\ &= \frac{2 * 3.14 * 95.54 * 0.23375}{60} = 2.337 \text{ w} \end{aligned}$$

6.2 BUOYANCY CALCULATIONS

For a body to float on water, the mass of the water displaced by the immersed body should be greater than the mass of the body.

Total immersed volume:

$$\begin{aligned} \text{Body} &= \frac{1}{2} * \pi * r^2 * h \\ &= \frac{1}{2} * \pi * (0.06)^2 * (0.11) \\ &= 6.22 * 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Frame} &= l * b * h \\ &= (0.16 * 0.025 * 0.035 * 2) + (0.11 * 0.025 * 0.035 * 2) \\ &= 4.72 * 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Wheel} &= \frac{3}{4} * 4 * \pi * r^2 * h \\ &= \frac{3}{4} * 4 * \pi * (0.05)^2 * (0.07) \\ &= 16.49 * 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Motors} &= 4 * \pi * r^2 * h \\ &= 4 * \pi * 0.04^2 * 0.04 \\ &= 8 * 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Total immersed volume} &= 6.22 * 10^{-4} + 4.72 * 10^{-4} + 16.49 * 10^{-4} + 8 * 10^{-4} \\ &= 35.43 * 10^{-4} \text{ m}^3 \end{aligned}$$

Total immersed volume = Volume of displaced Water

Mass of Water displaced = Immersed Volume * Density of Water

$$\begin{aligned} &= 35.43 * 10^{-4} * 10^3 \\ &= 3.54 \text{ kg} \end{aligned}$$

Mass of Body = 2.3 kg

Mass of water displaced > Mass of body

For the vehicle to lift off from ground, the motors should produce a thrust force greater than the weight of the vehicle.

Total weight of the body = 2.3 kg

$$\begin{aligned}\text{Minimum Thrust need for single motor} &= \frac{\text{weight}}{4} \\ &= \frac{2300}{4} \\ &= 575g\end{aligned}$$

For 1000 kV motor, Thrust = 800 g

Total thrust = $800 \times 4 = 3200$ g

$$\begin{aligned}\text{Total effective Thrust} &= \text{Total thrust} - \text{Weight of the body} \\ &= 3200 - 2300 \\ &= 900 \text{ g}\end{aligned}$$

III. TECHNICAL SPECIFICATIONS

SIZE AND WEIGHT

- Dimensions (L*W*H): 160*160*250 mm
- Weight: 2.3 kg
- Wheels: 100 mm diameter, 70 mm width
- Ground clearance: 25 mm

SPEED AND PERFORMANCE

- Max. Payload: 500 gm
- Drive type: 4 Wheel drive
- Wheel motor rating: 12 V, 150 rpm
- Propeller motor rating: 1000 kV, 900 gm thrust
- Max. Climb angle: 40°

BATTERY AND POWER SYSTEM

- Battery type: 3 cell, 11.1V Li Po
- Capacity: 5000 mAh
- Run time: 30 minutes
- Flight time: 15 minutes

COMMUNICATIONS AND CONTROL

- Type: 433 MHz, 2.4 GHz, TX/RX, Radio Frequency.
 - Range: 1 km for flight, 100 m for ground operation
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- Material: Aluminium chassis plastic and foam body.
 - Quadcopter – Aluminium frame, Hylum.
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- Motor Drivers: L293D
 - Flight controllers: KK2.1.5

IV. RESULTS

Completed Model (In All Terrains):



Figure: 3



Figure: 4



Figure: 5



Figure: 6

The unmanned vehicle was tested in all its operating modes of environment. The vehicle is able to move on land like a UGV. It is able to float on water and can move in all directions. It is able to fly like a quadcopter. The tests in all the environments are successful and thus the vehicle can achieve three modes of mobility and can be controlled by a radio transmitter receiver system.

CONCLUSIONS & FUTURE SCOPE

Development of unmanned vehicles is a challenging field of engineering which requires scientific, creative and innovative skills. There is a wide range of researches going in the field of unmanned systems, yet, research and development of a three mode mobility unmanned vehicle are rare and limited.

Varieties of problem and factors have to be taken into account in designing and fabricating an unmanned vehicle. The difficulties involved in maintaining stability and functional competency has limited the developments in three mode vehicles. The cost involved in the construction of unmanned vehicles is also a factor. The plans and designs must be flawless. One must also consider the weight, shape and

strength of the vehicle to avoid problems in stability and control in all three environments.

- The vehicle can be equipped with Night vision and thermal imaging cameras for situations where the environment is dark and harsh climate.
- Retractable quadcopter arms can be developed in place of redid fixed arm. This will increase the flexibility of the vehicle and make it more compact when needed.
- Synchronized co-operation of detachable drone for efficient navigation can be employed so that the surveillance can be achieved from even more altitude.

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