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UNMANNED AERIAL SURVEILLANCE VEHICLE

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Abstract - UAV is defined as an aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expandable or recoverable, and can carry a lethal or nonlethal payload. It is controlled either autonomously by on-board computers or by remote control of a pilot on the ground. Its usage is currently limited by difficulties such as satellite communication and cost. A Drone has been built that can be operated by radio frequency controller and send live audio-visual feedback.

The developed Drone is simulated in ANSYS to determine the forces and the stresses induced in the drone and whether it will hold up in various environments. The simulation shows a very stable operation and control of the developed Drone. Microcontroller based drone control system has also been developed where a RF transmitter and receiver operating in the frequency of 2.4 GHz are used for remote operation for the Drone.

Key Words: UASV, Aerofoil, Wing Loading, Aspect Ratio, Empennage

1. INTRODUCTION

An **UNMANNED AERIAL VEHICLE** (**UAV**), commonly known as a **DRONE**, is an aircraft without a human pilot onboard. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers. Compared to manned aircraft, UAVs were originally used for missions too "dull, dirty or dangerous" for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural, and other applications, such as policing, peacekeeping and surveillance, product deliveries, aerial photography, smuggling, and drone racing.

In our project we are going to construct a drone (aircraft) from scratch without copying or modifying any previously known or existing design. In this firstly we are going to calculate the dimensions of the drone using theoretical formulae's available, then according to the values obtained from the formulae we are going to construct prototypes to validate the calculations and modify the dimensions accordingly after performing basic trials on the prototypes. After performing trials on the prototypes we are going to modify the dimensions and construct a final structure which gives the most optimal performance, the thing to note here is that theoretical values obtained just serve as a base for designing the drone and that the final dimensions may vary from the values calculated.

Lastly after constructing the drone we will perform trials using a camera on board and then validate the structural stability of the drone using simulation software (ANSYS). India's present development of Unmanned Aerial Vehicle (UAVs) and Smaller Drones locally is pathetically low to meet a large number of requirements felt by the Indian Armed forces, with technology trajectory of UAV's and Drones moving to next level in the usage of their military applications.

Fig.1 A Hand launched UASV.

2. METHODOLOGY

India is one of the fastest developing countries in the world and its need for advanced technologies is on the rise to counter the various problems that it faces, internationally and domestically. These problems range from military surveillance to traffic management and forest surveys. In our project we are attempting to design and construct a drone which will help tackling the above mentioned problems.

In our project we are going to design and construct a drone from scratch. At first we finalised the span of the wings and then depending on the approximate total weight of the drone we designed the air foil of the shape to achieve the desired lift for a given speed.

Then we designed the fuselage, the shape of the fuselage was chosen as a square, but the edges would be made round to prevent excessive drag. The length of the fuselage and the position of the tail, rudder and wings was finalised depending upon the size of the wings, as the wings are ultimately responsible for the lift of the drone. Then on calculating the actual weight of the drone the type of motor and the propeller dimensions were finalised and calculated. At the end we are going to create a 3D model of the drone and simulate it in ANSYS software to find out the stresses and load acting in various conditions. Various velocities such as the stall velocity, maximum velocity will be calculated. Then the size of the batteries will be finalised depending upon the range of the drone, and the mechatronics system which includes the remote receivers will be attached to match with the functionality of the drone.

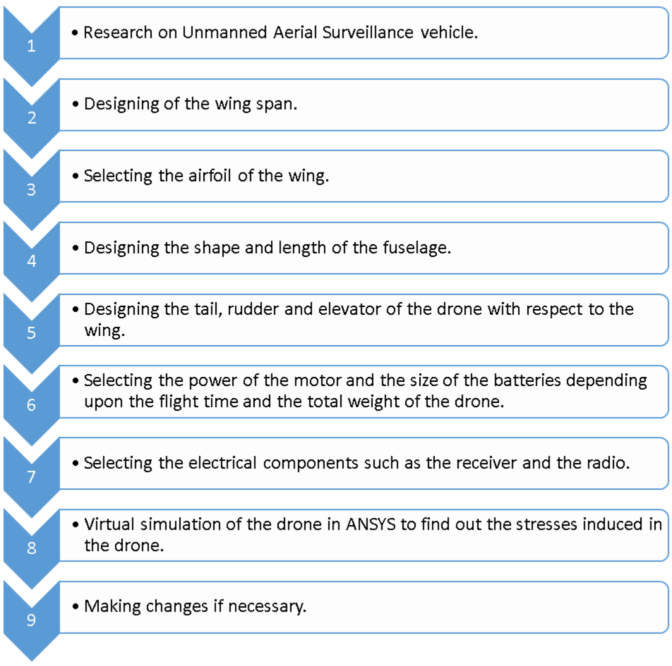

Fig. 2: Project Methodology

3. DESIGN PROCEDURE AND CALCULATION

1. Wing Design- To estimate the wing parameters, a value for wing loading (W/S) needs to be chosen. After considering similar airplanes, an initial estimate for (W/S) is taken as 6 kg/m^2.

$$S = \frac{W \times 9.81}{Wl}$$

S= Wing surface area (m^2)

Wl=Wing loading (kg/m^2) =6 kg/ m^2

Wing span (b) can be calculated from S and A (Aspect Ratio).

A= 7 (for a glider)

b=$\sqrt{S} \times \sqrt{A}$=$\sqrt{2.04375} \times \sqrt{7}$=3.8 m

But, one of the important aspect of our drone is that it should be easily accommodated in a backpack and readily assembled, keeping this in mind and the approximate weight of our drone we decided on the wing span accordingly.

Wing Span (b) =120cm=1.2m

According to the new wing span which we have selected, we get

$$S = \frac{b^2}{A} = \frac{1.2^2}{7} = 0.20571\ m^2$$

The root chord (r) and tip chord (t) of the wing can be obtained using the following equations.

Ω=taper ratio=0.8 (for high wing gliders)

r=$\frac{2 \times S}{b(1+\Omega)} = \frac{2 \times 0.20571}{1.2(1.8)} = 0.19m$

Similarly

t=0.23m

2. Wing Planform- We have used a combination of rectangular and elliptical wings because an elliptical wing is a wing planform shape that minimizes induced drag.

3. Aspect Ratio-

Aspect Ratio=$\frac{wing\ span}{mean\ chord}$

Mean Chord= $\frac{Mean\ Chord + Tip\ Chord}{2}$

Tip Chord=20cm=0.2m

Root Chord=17.5cm=0.175m

Mean Chord= 18.75cm=0.1875m

Aspect Ratio (AR) = 6.5:1

4. Wing Loading- Wing Loading (Approximate) = Total weight of the aircraft/ wing area

Total Approximate weight of the drone= 1.25 kg=1250gm

Wing area=wing span*mean chord=120*18.75=2250 cm sq=0.2250 m^2

Wing Loading=5.55kg/m^2

5. Air Foil Design- The airfoil which we have selected is **Selig S7055 low Reynolds number airfoil or S7055 airfoil.**

6. Spar Design Spar Thickness= 2cm

7. Sizing the Stabilizer Surfaces (Analytical Calculation)

- Horizontal Tail Volume Ratio

$$Cht = \frac{Sht \times Lht}{Sw \times MAC}$$

Cht= Horizontal Tail Volume Coefficient= 0.5 (from the above table)

Sht= Horizontal Tail Surface Area

Lht= Length between the aerodynamic centers of the wing and horizontal tail plane=0.55m (approximated)

Sw= Wing Surface Area= 0.225 m^2

MAC= Mean Air Chord= 0.185m

$$Sht = \frac{0.225 \times 0.185 \times 0.5}{0.55} = 0.03784\ m^2$$

$$bh = \sqrt{Ah} \times \sqrt{Sht}$$

bh= width of the horizontal tail

Ah= aspect ratio of horizontal tail surface=3.5 (taken as half of aspect ratio of the wing)

So we have,

$$bh = \sqrt{3.5} \times \sqrt{0.03784} = 0.37m$$

- Vertical Tail Volume Ratio

$$Chv = \frac{Shv \times Lhv}{Sw \times MAC}$$

We get Shv=0.01665 m^2

$$bv = \sqrt{1.75} \times \sqrt{0.01665} = 0.17m$$

8. Design of control surfaces:

- **Aileron Design**

Type of Aileron used= Strip Aileron

Length of the aileron= 60cm on each wing=0.6m

Breadth of the aileron= 5cm=0.05m

Thickness of the aileron=0.2cm=0.002m

Design of rudder and elevator

- **Rudder**

Length=0.175m

Width=0.065m

- **Elevator**

Length=0.145m

Width=0.06m

9. Fuselage Design: Length of the fuselage (LF) = 0.85m

Centre of gravity position from the start of the fuselage is=0.275m

Total Surface Area of fuselage=0.2975 m^2

Width of the fuselage (Wf) = 10cm=0.1m

Thickness of the fuselage=4mm=0.004m

Distance between elevator and center of gravity=0.575m

Distance between the propeller and center of gravity=0.33m

10. Avionics: Motor, Receiver, Transmitter, Battery, Electronic Speed Control, Propeller, Servo Motors

11. Performance Analysis of the plane:

a. Obtaining the minimum, maximum and operating velocity

As the maximum Reynolds number is 500,000(because above this the flow of air becomes turbulent over the wings), the formula for Reynolds number is

$$Re = \frac{density \times velocity \times chord\ length}{dynamic\ viscosity\ of\ air}$$

Density of air = 1.225kg/cc

Chord Length = 0.1875m

Dynamic viscosity of air = 0.0000179kg/m/s

Re = 500,000, calculating the velocity we get v=140.4kmph,

At this high velocity it is impossible to control the aircraft, hence the maximum Reynolds number is selected as 250,000, which gives a maximum velocity of 71kmph,

The Reynolds number for operational velocity was selected as 200,000 which gives operational velocity as 56kmph,

b. Analytically proving the values calculated are correct (for steady level flight)

To prove that at the given Reynolds number we get the appropriate amount of lift,

a) Re = 250,000

Coefficient of lift = 1.423

Lift $=\frac{density \times coefficient\ of\ lift \times velocity^2 \times area\ of\ wing\ span}{2}$N

Lift = 74.11N

Weight of the aircraft=$mass \times 9.81$N

= 1.25×9.81

=12N

As we observe that the lift generated by the aircraft is more than the weight of the plane the plane will rise and not stall.

b) Re=200,000

Coefficient of lift=1.383

Lift=$\frac{density \times coefficient\ of\ lift \times velocity^2 \times area\ of\ wing\ span}{2}$N

Lift=45.7N

Weight of the aircraft=$mass \times 9.81$N

= 1.25×9.81

=12N

As we observe that the lift generated by the aircraft is more than the weight of the plane the plane will rise and not stall.

c) Re=100,000

Coefficient of lift=1.316

Lift=$\frac{density \times coefficient\ of\ lift \times velocity^2 \times area\ of\ wing\ span}{2}$N

Lift=11.8N

Weight of the aircraft=$mass \times 9.81$N

= 1.25×9.81

=12N

As we observe that the lift generated by the aircraft approximately equal to the weight of the aircraft the aircraft will start to loose height which gives the minimum speed of the aircraft i.e. 26kmph

c. Determining the maximum angle of attack

At Re=200,000 the coefficient of lift is=1.383 and the

Maximum angle of attack (AOA) =12.815 degrees

For Re= 25000 Coefficient of lift= 1.423

Maximum angle of attack (AOA) = 12.815 degrees,

From the graphs we found out the maximum angle of attack for the aircraft which is 12.85 degrees as above this angle of attack the plane will stall.

- AOA max=12.85°

d. Thrust Calculations

In this section below we have calculated the minimum thrust required to get the plane of the ground.

Prerequisite formulae and values-

1) L(Lift) $= \frac{Coefficent\ of\ lift \times density\ of\ air \times velocity^2 \times Wing\ surface\ area}{2}$ (N)
2) W(Weight of the plane)= Mass×9.81(N)
3) T=Thrust(N)
4) D(Drag)= $\frac{Coefficient\ of\ drag \times desnity\ of\ air \times velocity^2 \times Total\ surface\ area}{2}$
5) Coefficient of lift=1.4
6) Density of air=1.225 kg/m^3
7) Wing surface area=0.225m^2

8) Coefficient of drag=0.05

9) Total surface area= wing area+fuselage area+empennage area=2.0025m^2

Now for achieving lift, the Lift force should be greater than the weight of the plane,

So L>W, from this equation we will calculate the minimum

velocity required for take-off, so converting the greater than sign to equality sign we get,

L= W

W=1.225$\times$ 9.81=12.01725N

So, $\frac{1.4\times1.225\times v^2\times0.225}{2}$=12.01725N

V=7.971 m/s or 28.7 kmph (Minimum Velocity required for take-off)

This velocity will be generated due to the thrust provided, now for the plane to move forward and generate enough lift, thrust should be greater than drag force,

So we have, T> D

Removing the greater than symbol and converting it into equality

T=$\frac{0.05\times1.225\times2.0025\times63.55}{2}$ =4N

e. The minimum thrust required for lift is 4N.

f. Endurance of the aircraft- Endurance of the aircraft is the maximum time the aircraft can stay in the air.

Case 1- The motor is operating at full capacity drawing 35A current.

Using a 2200 mah battery we have the endurance as $\frac{2200}{35\times1000}\times 60$=3.77min

- The endurance of the aircraft at maximum power is 3.77min

Case 2- The motor is operating at minimum capacity of 16A current

- Using a 2200 mah battery we have the endurance as 8.25 min.

Case 3- The motor is used at an optimal current of 26A (mid throttle position)

- We have endurance of the aircraft as 5min.

g. Range of the aircraft is 1.5 km and can be varied using a different set of transmitter and receivers.

h. Rate of climb

In order to increase altitude, we must add energy to the aircraft. We can do this by increasing the thrust or power available. If we do that, one of three things can happen:

1. We will increase kinetic energy (accelerate).

2. We will increase potential energy (climb).

3. We will do both, accelerate and climb.

If we desire to climb, we should hold the airspeed constant and use all excess power to increase our potential energy. Consequently, if we assume that we keep the airspeed approximately constant (called the quasi-steady assumption), then the governing equations become:

T-D-WsinΩ=mv=0

L-WcosΩ=0=mvΩ ...... (1)

H=VsinΩ

Where,

T- Thrust available

D- Total drag of the aircraft

W- Weight of the aircraft

L- Lift of the aircraft

Ω- Climb angle

H-Rate of climb

The first equation gives us the result:

sinΩ=$\frac{T-D}{W}$ .... (2)

Hence angle of climb is related to the excess of thrust available over the thrust required. The rate of climb can be obtained by substituting Eq. (2) for the sine term in the rate of climb equation:

$H = \frac{T-D}{W} \times V.$

So let us find the rate of climb for the optimum speed of 71kmph, the other values we have are

Tmax=330W=16.75N for 71kmph

W=1.25×9.81=12.265N

D=9.726N for speed of 71kmph

- So we have H=11.28 m/s.

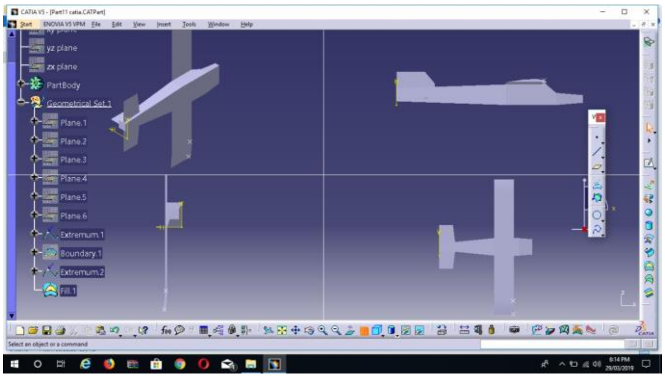

Fig- 3D Representation of the drone.

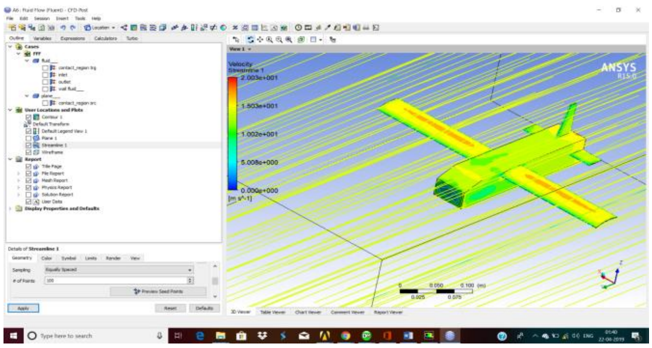

Fig- Velocity distribution over the plane

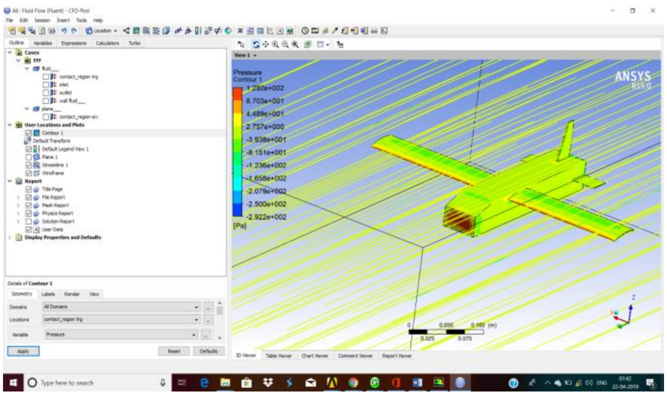

Fig-Pressure distribution over the plane.

5. CONCLUSIONS

We have presented a model and control methodology to construct an unmanned aerial vehicle using the standard design procedures. By characterizing the forces and torques experienced by the UAV during both flight and manipulation, we have designed the structure to handle the before mentioned forces and also to compensate for reactionary forces.

Our simulation and test results indicate that the UAV is stable and satisfies the prerequisite functions that it needs to without any difficulties. Motion capture using a camera does not disrupt aircraft stability and enables us to capture High Resolution videos and photos.

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