Conceptual Design and Prototyping of Radio Piloited Air vehicle

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Abstract- *The growth in the technology is enabling redefinition of early stages of aircraft design which has been rusticated mostly statistical and empirical approaches because of lengthy and costly process. The fabrication and manufacturing of aircraft was a challenging task but the development in technology and sophisticated devices has reduced the effort of developing the technological design. This has given rise to the technique of building a small sized aircraft which has an ability of the full sized aircraft which is called RC aircraft which is controlled by a radio transmitter of jumping frequency. The earliest examples of electronically guided model aircraft were hydrogen-filled model airships of the late 19th century. They were flown as a music hall act around theatre auditoriums using a basic form of spark-emitted radio signal.*

There are many types of radio-controlled aircraft. For beginning hobbyists, there are park flyers and trainers. For more experienced pilots there are glow plug engine, electric powered and sailplane aircraft. For expert flyers, jets, pylon racers, helicopters, auto gyros, 3D aircraft, and other high-end competition aircraft provide adequate challenge. Some models are made to look and operate like a bird instead. Replicating historic and little known types and makes of full-size aircraft as "flying scale" models, which are also possible with control line and free flight

The project basically redesigns the aircraft stabilizer for the better performance by the conceptual design which is calculated, prototyped and tested in the real world conditions comparing with the conventional stabilizer models.

Keywords- aircraft design, lift, drag and aspect ratio.

I. INTRODUCTION

A Remotely Piloted AirVehicle (often called RC aircraft or RC plane) is a small flying machine that is controlled remotely by an operator on the ground using a hand-held radio transmitter. The transmitter communicates with a Receiver within the craft that sends signals to servomechanisms (servos) which move the control surfaces based on the position of joysticks on the Transmitter. The control surfaces, in turn, affect the orientation of the plane.

Flying RC aircraft as a hobby grew substantially from the 2000s with improvements in the cost, weight, performance and capabilities of motors, batteries and electronics. A wide variety of models and styles is available.

Scientific, government and military organizations are also using RC aircraft for experiments, gathering weather readings, aerodynamic modeling and testing. Unmanned aerial vehicle (drones) or spy planes add video or autonomous capabilities, and may be armed

Some Major advantages of remotely controls aircrafts are:

- It was be virtually used in any environment in particular at altitudes inaccessible for manned aircrafts.
- Flight, trajectories can be precisely programmed, takeoff landing does not require large space.
- Equipments are easy for transportation
- Less impact or dangerous for testing

II. PROBLEM IDENTIFICATION AND PROBLEM DEFINITION

Problem Identification: Aircrafts suffers with more drag and during cross wind conditions stability of the aircraft is affected and control surfaces are not much affected during flight. The traditional design of the stabilizers of the aircraft is less effective for acrobatics and stalling is foreseen

Problem Definition: From the problem identified the aircraft stability should be more towards the positive side hence the stabilizers are redesigned and optimized in order to improve the stability band having less parasitic drag which is a combinational hybrid of v-tail and T-tail sharing the benefits of both.

III. DESIGN PARAMETERS

As Per Present T- tail design:

BENEFITS:

- Wind turbulence by the wing will not affect the active surface of the tail
- Theoretical calculations will be nearly equal to practical results
- Excellent glide ratio($\frac{V_f}{V_d}$)
- High performance aerodynamics and manoeuvrability

DISADVANTAGES:

- If the tail is out of propeller slip stream, then we have less control.
- Prone to deep stall
- Constant maintenance required
- Stronger vertical stabilizer required to support the horizontal one

As per present V-tail design:

BENEFITS:

- Reduced parasitic drag
- Reduced weight
- Higher stability compared to conventional tail
- Least stall

DISADVANTAGES:

- Requires higher surface area to compensate loss of active surface
- Requires stronger material to withstand stress

IV. LITERATURE REVIEW

1. **"Understanding the Structures and parts of the aircraft" authored by John Cutter and Jeremy Liber.** This paper is a study of the essential parts associated in an aircraft, importance of every individual part in an aircraft. It also explains about the different shapes of the aircraft [1].
2. **"Aircraft Design (Stability and Sizing of an aircraft design)" authored by Ilan Kroo.** Current research in the field of aircraft synthesis, sponsored by NASA and industry, includes the development of a new computational architecture for aircraft design, and its integration with numerical optimizations. Studies of unconventional configurations of the aircraft [2].
3. **"The Design of Airplane Empennage (tail design)" authored by Darrol Stinton.** It is a study on designing of an empennage of an aircraft. Explains about the different tail design that is usually adopted in the aircrafts. And also explains about the different shapes of the empennages [3].
4. **"Mechanics of Flight (Tail dihedral Effects)" authored by Warren F. Phillips**. Explains about the effects of nonlinear aerodynamics on aircraft stability, Effects of tail dihedral on longitudinal and lateral stability. And also explains about the dynamic stability constraints and centre-of-gravity limits, flight simulation in geographic co-ordinates [4].
5. **"Aircraft Design – A conceptual approach (Tail arrangement and geometry)" authored by Reston Virginia.** Explains the variability in flight characteristics due to the change in the geometry of the aircraft. And also explains the design parameters which are to be considered. And in this paper analysis of different shapes and structures of the aircraft is studied and experimented. As per the experimentation the semi symmetric shape of the fuselage is found to be very stable compared to other shapes [5].
6. **"Beginners Guide BY NASA (Tail design parameters with respect to the vertical stabilizer)" authored by NASA Glen Research Centre (Nancy Hall).** Explains the basic principles of the aircraft like the gliding properties of the aircraft, anti roll parameters of the aircraft and building of the aircrafts with the basic ratio [6].
7. **"Radio Controlled Model Aircraft" authored by Boddington David. It was published in 2004 in Crowood Press.** As in Chapter 1 it explains about the prototyping of a radio controlled model aircraft. It explains about the material that can be used in prototyping of the model aircraft and the electronic components suitable for the model aircrafts [7].

An increased downward force, produced by up elevator, forces the tail down and the nose up. At constant speed, the wing's increased angle of attack causes a greater lift to be produced by the wing, accelerating the aircraft upwards. The drag and power demand also increase. A decreased downward force at the tail, produced by down elevator, causes the tail to rise and the nose to lower. At constant speed, the decrease in angle of attack reduces the lift, accelerating the aircraft downwards. The rudder works by changing the effective shape of the aerofoil of the vertical stabilizer. As described on the shape effects, changing the angle of deflection at the rear of an aerofoil will change the amount of lift generated by the foil. With increased deflection, the lift will increase in the opposite direction. The rudder and vertical stabilizer are mounted so that they will produce forces from side to side, not up and down. The side force is applied through the centre of pressure of the vertical stabilizer which is some distance from the aircraft centre of gravity. This creates a torque on the aircraft and the aircraft rotates.

Normal aircrafts have V-tail design and T-tail configuration. The advantage of V-tail is the drawback of the other and vice-versa. Hence to overcome the drawback of each other, we have identified and considered the design parameters of both the tails which combines and forms a new Tail design which is highly efficient compared to both in major wind condition and which is concept attempted as an innovative configuration

V. OBJECTIVES OF PROJECT

The objectives of the design emphasis on

- With less parasitic drag compared to a t-tail
- Reduces stall from the T- tail design
- High manoeuvrability as that of the T-tail
- Dihedral tail benefits (provide better glide ratio)
- Reduced weight compared to T-tail

VI. METHODOLOGY

Design methodology is adopted for the fabrication and testing of the conceptual design

Preliminary design involves the identification of the materials available in market.

Conceptual design involves the combination of v tail and t tail design and model is fabricated and tested in real environmental conditions and parameters like take off time, stability and speed is considered.

CAD model of PSI tail design

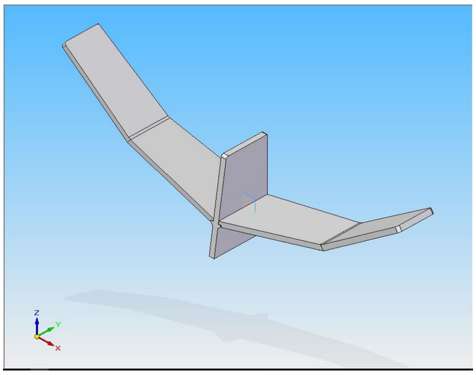

Figure 24 Psi Tail Design

- **THE HORIZONTAL STABILIZER**

The horizontal stabilizer usually creates a downward force which balances the nose down moment created by the wing lift force, which typically applies at a point (the wing center of lift) situated aft of the airplane's center of gravity. The effects of drag and changing the engine thrust may also result in pitch moments that need to be compensated with the horizontal stabilizer.

Both the horizontal stabilizer and the elevator contribute to pitch stability, but only the elevators provide pitch control. They do so by decreasing or increasing the downward force created by the stabilizer.

An increased downward force, produced by up elevator, forces the tail down and the nose up. At constant speed, the wing's increased angle of attack causes a greater lift to be produced by the wing, accelerating the aircraft upwards. The drag and power demand also increase.

A decreased downward force at the tail, produced by down elevator, causes the tail to rise and the nose to lower. At constant speed, the decrease in angle of attack reduces the lift, accelerating the aircraft downwards.

On many low-speed aircraft, a trim tab is present at the rear of the elevator, which th pilot can adjust to eliminate forces on the control column at the desired attitude and air speed. Supersonic aircraft have all-moving tail planes (stabilators), because shock waves generated on the horizontal stabilizer greatly reduced the effectiveness of hinged elevators. Delta winged aircraft combine ailerons and elevators –and their respective control inputs– into one control surface called an elevon.

- **THE VERTICLE STABILIZER**

In the rear of the fuselage of most aircraft one finds a vertical stabilizer and a rudder. The stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The vertical stabilizer prevents side-to-side, or yawing, motion of the aircraft nose. The rudder is the small moving section at the rear of the stabilizer that is attached to the fixed sections by hinges. Because the rudder moves, it varies the amount of force generated by the tail surface and is used to generate and control the yawing motion of the aircraft.

The rudder is used to control the position of the nose of the aircraft. Interestingly, it is NOT used to turn the aircraft in flight. Aircraft turns are caused by banking the aircraft to one side using either ailerons or spoilers. The banking creates an unbalanced side force component of the large wing lift force which causes the aircraft's flight path to curve. The rudder input insures that the aircraft is properly aligned to the curved flight path during the manoeuvre. Otherwise, the aircraft would encounter additional drag or even a possible adverse yaw condition in which, due to increased drag from the control surfaces, the nose would move farther off the flight path.

The rudder works by changing the effective shape of the aerofoil of the vertical stabilizer. As described on the shape effects, changing the angle of deflection at the rear of an aerofoil will change the amount of lift generated by the foil. With increased deflection, the lift will increase in the opposite direction. The rudder and vertical stabilizer are mounted so that they will produce forces from side to side, not up and down. The side force is applied through the center of pressure of the vertical stabilizer which is some distance from the aircraft center of gravity. This creates a torque on the aircraft and the aircraft rotates about its center of gravity.

On all aircraft, the vertical stabilizer and rudder create a symmetric aerofoil. This combination produces no side force when the rudder is aligned with the stabilizer and allows either left or right forces, depending on the deflection of the rudder.

Design Calculations

Required minimum area varies from a range of 30% to 50% of the overall wing area.

The wing area is found to be 0.25m²

From the literature survey and design, we get

1) (1/3) - (1/16) approximately, that is 28% of the overall wing area.
2) (1/3) – (1/8) approximately, that is 21% of the overall wing area.

Therefore, the overall effective area of the tail will be about 49% of the wing area.

Initial angle taken to be is
12.5 for 1) with respect to base (dihedral tail) and
35.5 for 2) with respect to base (V-Tail).
Elevator area was calculated to be 0.1225m².
Required rudder area:
According to the survey we get that the area of the rudder should be from 15%-25% of the overall wing area.
Since additional flaps are present we consider the area to be 15%
And due to the attachment of the elevator to the rudder some of the area will be ineffective so we assume some allowances and consider the area as 20% of the overall area of the wing.

The Area of the rudder will be = $\left(\frac{20}{100}\right) * 0.25$ = 0.5m².

Initially we assume the wing span(b) of the aircraft to be 1m. It will be the reference for the further calculation. We use the **GOLDEN RATIO** that is **1:$\sqrt{2}$.**

Golden ratio principle = Body: Wing span
Therefore, the Fuselage or Body = 0.7071m.
Chord length = 0.25m (1/4th of the wing span)
Area of the wing span(S) = (Wing span * chord length)
= 1*0.25 = 0.25m²

Aspect Ratio= $\frac{b^2}{S} = \frac{1^2}{0.25} = 4$
Therefore, maintained aspect ratio = 4

Tail design Calculations:

Tail or Stabilizer design

Terms used, S_H = Area of the horizontal stabiliser
S_V = Area of the vertical stabiliser

- Aspect Ratio of the Horizontal Stabiliser:

$$AR_H = \frac{AR_{wing}}{2}$$
$$= \frac{4}{2}$$
$$AR_H = 2$$

- Root Chord(Croot):

Croot= $\frac{(2*S_{wing})}{(b*(1+TR)}$

$=\frac{(2*0.25)}{(1*(1+1)}$

Croot = 0.25m

- Chord Tip (Ctip):

Ctip = TR*Croot
= 0.25m

- Standard Mean Chord (SMC):

SMC = $\frac{S}{b}=\frac{b}{AR}$

$=\frac{1}{4}$= 0.25m

- Mean Aerodynamic Chord (MAC):

MAC = $\frac{(2*C_{root}(1+TR+TR^2)}{(3*(1+TR)}$

MAC = 0.25m

- Aerodynamic Center (X):

X =$(C_{root} - \text{MAC}) + \left(\frac{MAC}{4}\right)$

X= 0.0625m

- Aerofoil Design:

Lift = Weight
$0.5 * \rho * (V^2) * CL * Swing$ = M*g
$0.5 * (1.125\ kg/m^3) * (18m/s) * CL * (0.25m^2)$
=1.3
CL = 0.4176
For CL = 0.4716

- Angle of attack (α) = 3-4 degree
- Drag Co-efficient:

$C_D = C_{DO} + \frac{C_L{}^2}{\pi * e * AR}$

Where, e=Oswald co-efficient=0.9(assumed efficiency)

C_{DO}= zero lift drag co-efficient $= C_{fe} * \frac{S_{wet}}{S_{ref}}$

S_{wet}= 95% of S_{ref}

C_{fe} =0.7 assumed due to friction

$C_{DO} = 0.7 * \left(\frac{95}{100}\right)$

C_{DO} = 0.665

Substituting all these values to find drag co-efficient
We get, C_D = 0.6846
From ideal conditions
Thrust = Drag
Thrust = $0.5 * \rho * (V^2) * C_D * Swing$
Thrust = 33.967N
Consider Thrust to Weight ratio
T: W = $\frac{33.967}{23.397}$
T: W = 1.451: 1

- Tail Design Parameter:

Area of Tail = ST = 75% – 80% of the area of the wing
ST = 0.2m²

Angle = $\tan^{-1}\left(\sqrt{\frac{S_V}{S_H}}\right)$

To find $\frac{S_V}{S_H}$:

For Standard parameter $\frac{S_V}{S_H}$ = 3/4 of wing span

Therefore, Angle = $\tan^{-1}\left(\sqrt{\frac{0.75}{0.25}}\right)$

Angle = 52.3 °.
Area of horizontal stabiliser, SH = $Area\ of\ the\ tail * (sin(angle)^2)$
= 0.1252m²
Area of vertical stabiliser, SV = $Area\ of\ the\ tail * (cos(angle)^2)$
= 0.075m²
Note: From the standard parameter the above SH and SV should be less.
Aspect ratio of the horizontal stabiliser, (AR)H = 2

(AR)H=$\frac{b^2}{S_H} = \frac{b_H{}^2}{0.125}$

b_H= 0.5m-o.55m

b_V = 0.24m-0.28m.

VII. TEST AND ANALYSIS

The table explains the observation and tabulation of the convectional tail model which is build and tested in same environment in open wind conditions and approximately same temperature.

Sl.No	Parameter	Trial 1	Trail 2
1	Takeoff Time (in sec)	11.2	10.98
2	Takeoff Distance (in meters)	13.2	13.1
3	Flight Time for 2200mAh battery (in min)	15	13
4	Landing time (in sec)	15.5	-
5	Maneuverability	Good	Good
6	Sensitivity	Not accurate	Not accurate
7	Auto anti-roll	Not seen	Not seen
8	Stability	Average	Average

The table explains the observation and tabulation of the PSI tail model which is build and tested in same environment in open wind conditions and approximately same temperature

Sl.No	Parameter	Trial 1	Trail 2
1	Takeoff Time (in sec)	12.1	11.98
2	Takeoff Distance (in meters)	14.4	14.1
3	Flight Time for 2200mAh battery (in min)	15	14
4	Landing time (in sec)	15.1	-
5	Maneuverability	Better	Better
6	Sensitivity	More sensitive	More sensitive
7	Auto anti-roll	Yes	yes
8	Stability	More stable	More stable

VIII. RESULTS

The experiments were conducted and the results obtained are listed below.

1) Higher Stability of the aircraft
2) Easy Manuverability
3) More sensitive control surface
4) Auto Anti-roll
5) Lift generated is high
6) Speed is more
7) High directional stability and drag is less
8) Better Gliding property

IX. CONCLUSION AND SCOPE FOR FUTURE WORK

By testing the flight characteristics in the real environmental wind conditions and found that performance of the Psi Tail designed airvehicle was responsive and more agile to the motion of the wind. And sensitivity was at its best even the tiny defection can defect the flight to make the required manoeuvrability was a good feedback from the rc fabricated model. The wing also supported and provided greater lift at required times and found the best at its performance when the same wing is used in both the model as a result which helped the observer and the rc pilot to take a convenient decision during flight time and be more secure. It was also found that drag was reduced to some extend because the aircraft always was on the pointed direction with the nose tilted a little downwards which represented the thrust to weight ratio was more. During the CG balancing the tail was found to heavy but during flight it was normal at its performance and turns was best and most responsive and speed during a curve was great thus reduced drag.

X. FUTURE WORK

The work carried out is a demonstration model which can further be improvised and developed by fabricating and reinforcing with suitable materials so that the angle maintenance and support can be provided in a better way which influences the flight characteristics with better stability and performance oriented plane.

The built material used as of now is DEPRON which is very light and the strength is very less, hence it is suitable only for RC planes, but when it is developed with stronger materials like carbon fibre or even aluminum for real accessed planes the real performance of the plane is seen.

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