Design, Fabrication and Aerodynamic Analysis of RC Powered Aircraft Wing

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Abstract - *A Radio-controlled (model) aircraft (often called RC aircraft or RC plane) is controlled remotely by a hand-held transmitter and a receiver within the craft. Flying RC aircraft as a hobby has been growing worldwide with more efficient motors (both electric and miniature internal combustion and jet engines) lighter and more powerful batteries and less expensive radio systems. After designing the aircraft wing, fabrication is one of the important factors to be considered. Fabrication mainly depends on the type of material employed in manufacturing the aircraft by considering the availability, cost, durability, strength and how easily it can be made into required shape. This paper is based on designing a light weight, electronically controlled glider with operating frequency of 2.4 GHz. This paper did not concentrated on electronic components as the components used are readily available in markets and need not be programmed by the users. The aircraft wing considered in this paper was designed to have optimum lift and drag characteristics. The aerodynamic characteristics over the wing had been validated with the experimental data using low subsonic wind tunnel.*

Key Words: RC Aircraft, Wingspan, Lift, Angle of attack, Drag, Batteries

1. INTRODUCTION

RC plane represents Radio Control Aircraft or Airplane is a small flying machine that is controlled remotely by an operator on the ground using a hand-held transmitter. The transmitter communicates with a receiver within the crafts 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 [1]. Flying RC aircraft as a hobby grew substantially with improvements in the cost, weight, performance and capabilities of motors, batteries and electronics. A wide variety of models and styles is available [2]. 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. During World war II, the U.S Army and Navy used radio controlled planes called Radio planes as artillery target drones [4]. The first thing one must realize about a radio controlled model aircraft is that it is not a toy. The model is a real aircraft which flies and operates by the same principles as its full scale counterpart [3]. The only difference is size and weight. Models fly at anywhere between 20 and 150 MPH with the average trainer being between 40 and 60 MPH. These are not slow vehicles, nor can they be flown in a normal backyard. And just like their bigger brothers, they required a learned skill to be controlled properly. It is not simply a matter of pushing a button to take off, another to land, etc.

2. ELECTRICAL POWERED RC AIRCRAFT

2.1 Wing Selection

There were 3 choices for the types of wing we could use, Rectangular, Elliptical and Tapered. The most commonly used wing for RC planes are Rectangular [3].

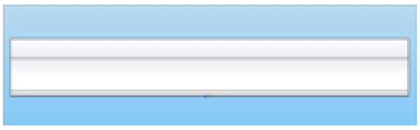

Figure 1: Rectangular Wing

The rectangular wing is the best wing for usage from a manufacturability point of view. The rectangular wing has a tendency to stall rest at the wing root and provides adequate stall warning, adequate aileron effectiveness, and is usually quite stable. It is also often favored for the design of low cost, low speed R/C planes.

2.2 Airfoil selection

An airfoil is a shape of the wing, an airfoil-shaped body moved through a fluid produces aerodynamic force. The component of this force perpendicular to the direction of the motion is called lift. The lift of the airfoil is primarily the result of its angle of attack and shape [5]. The below figure represents the airfoil terminology and by altering each of the above features of an airfoil, the designer is able to adjust the performance of the wing so that it is suitable for its particular task. For example, a crop duster may have a thick, high camber wing that produces a large amount of lift at low speed. Alternatively, a jet would have a thin wing with minimal camber to allow it to cruise at high speeds.

Figure 2: Airfoil terminology

2.3 Fuselage Selection

Fuselage design focused on three different models, namely Conventional Monoplane, Bi-Plane and N-Plane. While lifting the fuselage, one could potentially reduce wing loading, which was the potential problem of executing a low-weight construction along with the excessive airfoil thickness to accommodate a variety of potential loads. Thus a conventional design was found to be often favored within the model building community due to ease of construction. Therefore in this paper the Conventional type fuselage was used.

2.4 Tail Design or Empennage Design

The empennage also known as the tail or tail assembly, of most aircraft gives stability to the aircraft, in a similar way to the feathers on an arrow. Most aircraft feature empennage incorporating vertical and horizontal stabilizing surfaces which stabilize the flight dynamics of pitch and yaw, as well as housing control surfaces. In spite of effective control surfaces, many early aircraft that lacked stabilizing empennage were virtually not flyable. Today, only a few (often relatively unstable) heavier than air aircraft are able to fly without empennage.

There are 3 different tail designs namely Conventional, V-Tail and H-Tail. While the H-Tail increases effectiveness of the horizontal control surfaces through the winglets, it also adds increased weight to the design since we require a number of vertical surfaces with their control servos, which may not be considerable. While the V-Tail provided a number of benefits, the team felt that we could get the same performance characteristics from a simpler design given the speed we were traveling at. Additionally, no weight was expected to be saved by using a more complicated tail design.

The Conventional design is well known for its low risk and ease of control and manufacturability. A conventional design is also widely used because it is the most efficient tail design for the speed R/C planes are expected to fly it. And so the Conventional design is good for low speed RC planes.

2.5 Control Surfaces

Ailerons:

These are the control surfaces situated at the trailing edge of the wing to give it the roll motion. Ailerons move in opposite direction to each other that is they have differential action.

Rudder:

It is a control surface unites with vertical stabilizer to control the yaw motion of the aircraft.

Elevator:

It is a control surface unites with horizontal stabilizer to control the pitching motion of the aircraft.

3. DETAIL OF DESIGN

3.1 Important terms

The basic parameters to be considered are wing span, chord length, Plan form area, Tip chord, root chord, aerodynamic centre etc.

1. Chord length (c):

Chord refers to the imaginary straight line joining the leading and the trailing edges of an airfoil. The chord length is the distance between the trailing edge and the point on the leading edge where the chord intersects the leading edge. The designed Chord length (c) for the wing is 11 cm.

2. Wing span (b):

It is the maximum extent across the wing of an aircraft or of a bird or other flying animal measuring from tip to tip. The designed Wing span (b) of the wing is 55 cm.

3. Aspect ratio (AR):

The aspect ratio of the wing is the ratio of its span to its mean chord. It is equal to the square of the wing span divided by the wing area. Thus, a large narrow wing has a high aspect ratio, where as a short, wide wing has a low aspect ratio.

Aspect Ratio (AR) = b/c

Where,
b – Wing span
c – Chord length

AR = 55/11

The designed aspect ratio of the wing is 5 because our aircraft is homebuilt so according to the given we have chosen it to be in the correct range.

4. Planform Area (Swing):

It is the area of the wing as viewed from above the wing, looking along the lift direction.
Swing = b^2/AR cm^2 = 3025/5

5. Wing Loading:

An aircraft with a low wing loading has a larger wing area relative to its mass, as compared to an aircraft with a high wing loading. The faster an aircraft flies, the more lift can be produced by each unit of wing area, so a smaller wing can carry the same mass in level flight.

Wing loading = body mass/Swing gm/cm^2

= 191/605 gm/cm^2

= 0.3157 gm/cm^2

Wing loading must not exceed 0.6 – 1.3 gm/cm^2, so it is in the correct range.

6. Taper Ratio (TR):

Taper ratio is defined as the wing span divided by the average chord. Ratio of the chord at the tip to the chord at the root angle between the line of 25% chord points and the longitudinal axis.

7. Root Chord (CROOT):

We call the chord length near the fuselage is root chord.

CROOT = 2* Swing/b*(1+TR)

= 2* 605/55*(1+1)

= 1210/110

= 11 cm

It is a Rectangular Straight wing so CTIP is also same.

8. Aerodynamic Centre (x):

The aerodynamic centre is the point at which the pitching moment coefficient for the aerofoil does not vary with lift coefficient (angle of attack), so this choice makes analysis simpler.

X = (CROOT – C) + C / 4

= (11-11) +11/4 =2.75 cm

3.2 Wings

Wing is the most important part of the plane which provides lift, which causes the plane to fly. The type of wing we have selected is monoplane, which is most popularly used over multi plane configuration because the adjacently placed wings generate more drag and reduce efficiency.

The position of the wing on the fuselage is High wing which is attached to the higher position of the fuselage, it gives stable flight, and it is not aerobatic.

3.3 Airfoil

We have chosen Asymmetrical airfoil, because the asymmetrical airfoil has a higher coefficient of lift than the symmetrical airfoil. On asymmetrical airfoils, the top edge is shaped differently than the bottom edge, which changes the way air flows over it. This causes the air to move faster, which creates more lift. The asymmetrical aerofoil we have used is GOTTINGEN 526.

Figure 3: ***Gottingen 526*** **Airfoil**

3.4 Lift and Drag coefficient

The lift coefficient (C_L) is a dimensionless coefficient that relates the lift generated by a lifting body to the fluid density around the body, the fluid velocity an associated reference area. A lifting body is a foil or a complete foil-bearing body such as a fixed-wing aircraft. The plot of lift coefficient versus Angle of attack over Gottingen 526 Airfoil is shown in figure below.

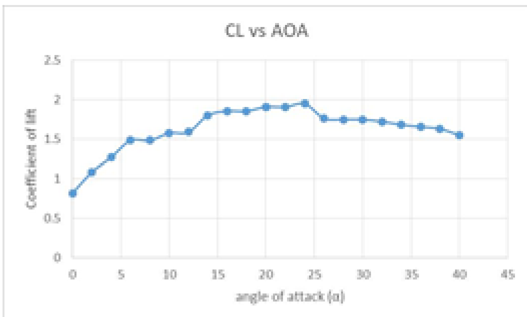

Figure 4: CL vs AOA

From above figure, the maximum value of lift coefficient equal to 1.94 is observed at an angle of attack of 24 degree.

In fluid dynamics, the drag coefficient (CD) is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment, such as air or water. The plot of drag coefficient versus Angle of attack over Gottingen 526 Airfoil is shown in figure below.

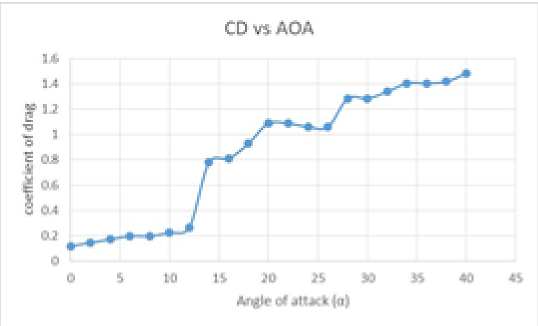

Figure 5: CD vs AOA

4. COMPUTATIONAL ANALYSIS

Generating mesh is neither easy nor fun. But mesh generation is where you have the most direct influence on how fast, how converged and how accurate your CFD solutions is. Because of that you need a mesher that is flexible and reliable and so the Gridgen tool is used. The details of the mesh generated over the wing are given in figure below.

Type of Grid	: Multi block structured grid
Total Number of grid	: 14340
Cell type	: Quadrilateral element
Number of Element	: 13924
Number of blocks	: 3 blocks
Boundary conditions	: Wall and Pressure far field

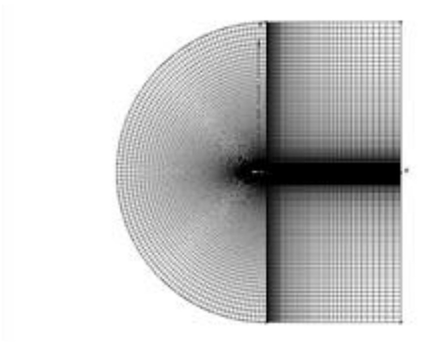

Figure 6: Mesh generated over wing

ANSYS-FLUENT contains the broad physical modeling capabilities needed to model flow, heat transfer, turbulence and reactions for industrial applications ranging from airflow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing. In this paper, Ansys-Fluent has been used to analyze the lift and drag coefficients for the aircraft wing. The Input conditions used for the CFD analysis are given below.

Model	: Viscous-Spalart-Allmaras (1 eqn)
Material	: Fluid
Density	: Ideal Gas
Viscosity	: Sutherland
Operating condition	: 0 pa (Operating pressure)
Boundary conditions	: Walls and Pressure far field
Mach number	: 0.05
U-velocity	: 0.912545
V-Velocity	: 0.406736
Temperature	: 300 K

Contour Plots:

Pressure can be used to calculate forces such as lift, drag or torque on objects integrating the pressure over the surface of the object.

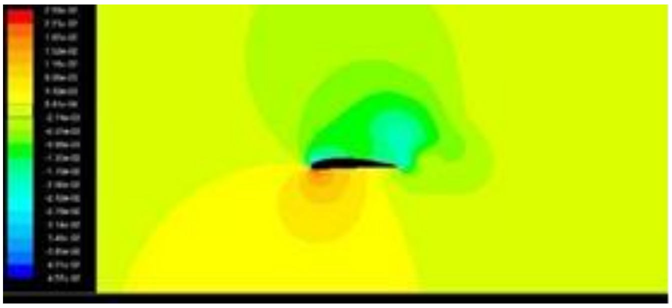

Figure 7: Pressure contour over wing

The above figure shows the pressure distribution over the wing at 24° Angle of attack. The pressure at the bottom of the airfoil is higher than the upper airfoil.

A method of measuring stream discharge in which point velocity measurements are translated into average cross sectional flow velocities by contouring the point velocities.

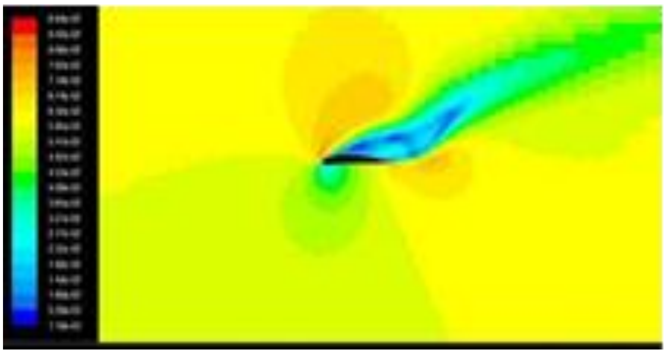

Figure 8: Mach contour over wing

The above figure shows the contours of Mach number over the wing. The Mach contour plot reveals high velocity at the upper surface and low velocity at the bottom surface of the wing.

5. TAIL CONSTRUCTION

The type of tail section used in this paper is conventional tail. This configuration includes one horizontal tail (two left and right section); located on the tail of the fuselage and one vertical tail (one section) located on top of the tail of fuselage. Both vertical and horizontal tails are located and mounted to the tail of fuselage.

5.1 Horizontal Stabilizer

The design of horizontal stabilizer had been made by calculating the following parameters.

5.1.1 Stabilizer tail area (st)

Stabilizer area should be around 14 to 15 percentage of the wing area.

Wing Area = 605 cm^2
15% of wing area = 0.15 * 605 Tail Area (St) = 90.75 cm^2

5.1.2 Tail span (bt)

Tail span (bt) = (ARt * St) ^ 1/2 Where,

ARt = Aspect Ratio of Tail should be less than Wing = 4.
Tail Span (bt) = 19.05 cm

5.1.3 Tapper ratio (TRt)

Tapper ratio of the tail = 0.66 (assumed)

5.1.4 Tail root chord (Croo t)

Tail root chord = 2* St/ (bt (1+TRt)) = 2* 90.75 / (19.05(1+0.66)

= 181.5/31.54

Tail Root Chord (Croot t) = 5.75 cm

5.1.5 Tail tip chord

Tip Chord (Ctip) = (TRt * Croot)

= (0.66 * 5.75)
= 3.75 cm

Tail angle should be 1 to 1.5 degrees less than α.

α= 3 degree (wing)
αt = 2 degree (Tail)

Figure 9: Horizontal Stabilizer

5.2 Vertical Stabilizer

The design of vertical stabilizer had been made by calculating the following parameters

5.1.1 Chord tip

Chord Tip (C tip) = 1 * D

Where,
D = Fuselage Height (6.2 cm)

Ctip = 6.2 cm

5.1.2 Root chord

Root Chord (C root) = 2 *D Croot = 12.4 cm
Span = 2*D Span = 12.4 cm

Figure 10: Vertical Stabilizer

6. ELECTRONIC COMPONENTS

The electrical components used for fabricating the RC powered aircraft are listed below,

Brushless Motor	: 1600 kv
Servo (4 Nos)	: 180 degree
ESC	: Electronic Speed Control
LIPO Battery	: 11.1 V
Fly Sky Transmitter	: 2.4 GHZ
Fly Sky Receiver	: 2.4 GHZ

These components are readily available in markets and need not to be programmed by the user.

7. FUSELAGE CONSTRUCTION

The fuselage construction consists of Front section, Mid-section and Aft section.

Front Section:
From the basic configuration of RC Plane, the front section should be 1.3 of chord length and so the front section length will be 14.3 cm.

Mid-Section:
This section is for placing the wing that is 11 cm chord length.

Aft Section:
This section should be 2.4 of chord length, i.e. is 26.4 cm.

8. LANDING GEAR

Landing gear is the undercarriage of an aircraft, may be used for either landing or take off. It absorbs the landing shocks, dampen the vibration etc. The type of Landing gear used in this paper is Tail Dragger which is fabricated using aluminum sheet.

9. FABRICATION

Based upon the above calculations, wing section, fuselage section, tail section was fabricated using foam material as sown in figure below.

Figure 11: Wing construction

Figure 12: RC Aircraft model

10. CONCLUSION

From the above methodology and concepts the RC powered Aircraft wing had been designed and tested both experimentally and computationally. The results of both tests were compared. And also the wing is placed in the working model and was successfully flown. The applications of RC Plane were studied.

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