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DESIGN AND CONSTRUCTION OF A RADIO CONTROLLED AIR PLANE BY USING DELTA WING

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Abstract- *The quintessence of the intense theory models of the aeronautical study could be apprehended with the hands-on experience on the real-time construction of flights or similar aerodynamic structures. The project was launched to design and construction of a delta wing RC controlled airplane. The delta wing is commonly used for the high speed airplane. The delta wing has a large enough angle of rearward sweep and for this reason the wing's leading edge will not contact the shockwave boundary formed at the nose of the fuselage as the speed of the aircraft approaches and exceeds transonic to supersonic speed. The delta plan form has a large wing area than a traditional wings that's why it produces a useful lift with very low wing per unit loading and permitting high maneuverability in the airframe. Because of its advantage a delta wing shape airplane has been modeled and construct in this project. The main concern of this project is construct a plane model and control it by Radio Control system.*

Keywords: Template, Double column, Times New Roman, References and Nomenclature (maximum 5 key words)

1. INTRODUCTION

Aeronautics is the study of the science of flight. RC planes are small model radio-controlled airplanes that using electric motor, gas powered IC engines or small model jet engines. The RC Airplanes are flown remotely with the help of a transmitter with joysticks that can be used to fly the aircraft and perform different maneuvers. The transmitter comes also with a receiver which is installed inside the model RC Airplanes which receives the commands send by the transmitter and controls servos. The servos are small motors which are mechanically linked to the control surfaces e.g. ailerons for roll control, elevator for pitch control and rudder for yaw control. The servos moves the control rods (which are small rods that connect the servo to different flight control e.g. to elevator etc.) which in turn moves the control surface be it elevator, flaps, aileron or rudder. An RC Airplane can be controlled in flight by using the transmitter from where one can control pitch, yaw and roll of one's RC Airplane and one can also control the throttle settings. The receiver which accepts the transmitter signal and the servos attached to it are run on rechargeable batteries. Most popular rechargeable batteries for RC Airplanes us include Ni-Cd (Nickel Cadmium) and Li-Po (lithium-Polymer). Lithium polymer lasts longer and more powerful than there Ni-Cd counterparts but a bit more expensive. Generally RC planes are consist of straight type wing which is easy to make and control. For the delta shape wing, it gives high speed flight as well as easy design and manufacturing, Strength. As the angle of attack increases, the leading edge of the wing generates a vortex which energizes the flow and giving delta a very high stall angle. In delta wing the air flow is divided into two components on the leading edge. One component is perpendicular to the leading edge and the other component is parallel to this edge. Only the first component is essential in lift generating, while the parallel component produces drag force. Therefore in these wings lift to drag ratio is lower than other wings. [2]

2. BACKGROUND

Between 1529 and 1556 Conrad has wrote a book in which he described rocket technology, involving the combination of fireworks and weapons technologies. This manuscript was rediscovered in 1961, in the Sibiu public records (Sibiu public records Varia II 374). His work dealt with the theory of motion of multi-stage rockets, different fuel mixtures using liquid fuel, and also introduced delta shaped stabilizers. As the manuscript was discovered only in 1961 until recently the conception of such stabilizers and their name had been suggested in the 17th century by the polish-Lithuanian military engineer Kazimierz Siemienowicz. The development of the swept and delta wing plan form enabled practical attainment of the high speeds promised by the invention of the turbojet engine and the solid-and-liquid-fueled rocket. Refining the swept and delta plan forms from theoretical constructs to practical realities involved many challenges and problems requiring creative analysis and study by NACA and NASA researchers. The high speed swept wing first appeared in the mid -1930s and like most elements in aircraft design, was European by birth. The first practical uses of delta wing came in the form of so called "Tailless delta" i.e. without the horizontal tail plane. In fact the design were at the same time also the first flying wings. It could be argued if 1924 Cheranovsky designs, having one of a kind parabolic plan form, fit the category of delta wings. Nevertheless, a triangular wing was pioneered especially by Alexander Lippisch in Germany. He was first to fly tailless delta aircraft in 1931 followed by four improved designs. None of these was easy in handling at slow speeds, and none new saw widespread service. Pure delta- wing fell out of favor somewhat due to their undesirable characteristics notably flow separation at high angles of attack (swept wings have similar problems), and high drag at low altitudes. This limited them primarily to high-speed, high-altitude interceptor roles. Tailed delta adds a conventional tail plane (with horizontal tail surfaces), to improve handling. Cropped delta is the type which has cut off tip, this helps avoid tip drag at high angles of attack. In another variant known variously as Compound delta, double delta or Cranked arrow. The inner part of the wing has a very high sweepback, while the outer part has less sweepback, to create the high-lift vortex in a more controlled fashion, reduce the drag and thereby allow for landing the delta at acceptably slow speed. [3]

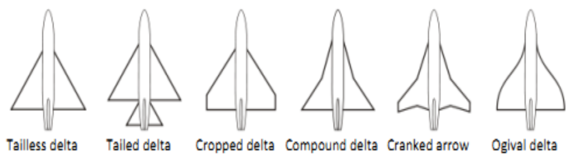

Fig.1: Various type of Delta Wings.

Generally RC plane consists of the following parts and wing shape generally straight type.

- RC Electric Motors
- Fuselage
- Wings
- Engine Cowl
- Propeller
- Horizontal Tail
- Vertical Tail
- Ailerons
- Flaps
- Elevators
- Rudder
- Landing Gear

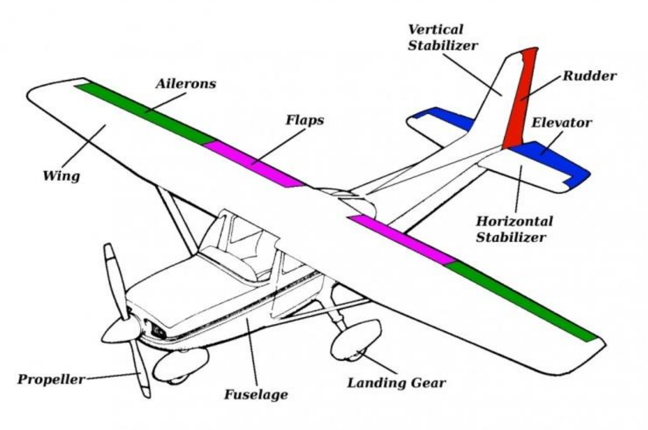

Fig.2: Various parts of Radio Controlled plane

3. BASIC AERODYNAMICS

The air flow over an airfoil and considering the stream tube A flows over the top surface, and stream tube B flows over the bottom surface. Both stream tubes originate in the free stream ahead of the airfoil. As stream tube A flows toward the airfoil, it senses the upper portion of the airfoil as an obstruction, and stream tube A must move out of the way of this obstruction. In so doing, stream tube A is squashed to a smaller cross-sectional area as it flows over the nose of the airfoil. [1]

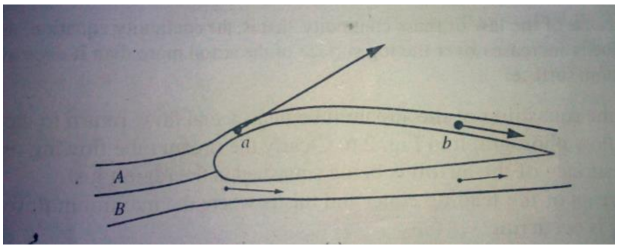

Fig.3: Flow velocity over an airfoil shape.

In turn, because of mass continuity (ρAV=constant), the velocity of the flow in the stream tube must increase in the region where the stream tube is being squashed. Hence the higher velocity of the upper surface of airfoil so from the Bernoulli's equation: (1)

$p + \frac{1}{2}\rho V^2 = constant$ …..…. (1)

Clearly shows that where the velocity increases, the static pressure decreases. This trend is the same for both compressible and incompressible flow. That's how lifting of wing produces. [2]

Another alternative explanation also describe the same phenomena. The wing deflects the airflow such that the mean velocity vector behind the wing is canted slightly downward. Hence the wing imparts a downward component of momentum to the air; that is, the wing exerts a force on the air, pushing the flow downward. [1]

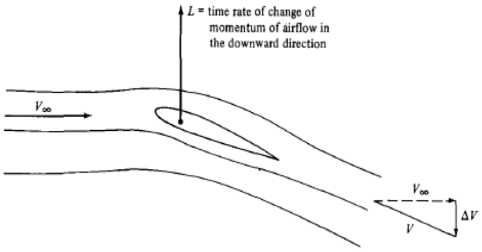

Fig.4: Relation of lift to the time rate of change of momentum of the airflow.

From the Newton's third law, the equal and opposite reaction produces a lift. However this explanation really involves the effect of lift, and not the cause. In reality, the air pressure on the surface is pushing on the surface, hence creating lift in the upward direction. As a result of equal and opposite principle, the airfoil, surface pushes on the air, imparting a downward force on the air, whish deflects the velocity downward. Hence the net rate of change of downward momentum created in the airflow because of the presence of the wing can thought of as an effect due to the surface pressure distribution; the pressure distribution by itself is the fundamental cause of lift. The preceding explanation of the generation of lift applies also to flat plates as well as curved airfoil shape. [1]

3.1 Effect of swept wing on critical Mach number

Consider the plan view of a straight wing. Assume this wing has an airfoil cross section with a critical Mach number $M_{cr} = 0.7$. (Remember from Sec. 5.10 that for M_∞ slightly above M_{cr}, there is a large increase in drag. Hence, it is desirable to increase M_{cr} as much as possible in high-speed subsonic airplane design.) Now assume that we sweep the wing back through an angle of, say, 30°, as shown in Figure. The airfoil, which still has a value of $M_{cr} = 0.7$, now "sees" essentially only the component of the flow normal to the leading edge of the wing; i.e., the aerodynamic properties of the local section of the swept wing are governed mainly by the flow normal to the leading edge. Hence, if M_∞ is the free stream Mach number, the airfoil in Figure is seeing effectively a smaller Mach number, $M_\infty \cos 30°$. As a result, the actual free stream Mach number can be increased above 0.7 before critical phenomena on the airfoil are encountered. In fact, we could expect that the critical Mach number for the swept wing itself would be as high as 0.7/cos 30° = 0.808. This means that the large increase in drag would be delayed to M_∞ much larger than M_{cr} for the airfoil, something much larger than 0.7, and maybe even as high as 0.808. Therefore, we see the main function of a swept wing. By sweeping the wings of subsonic aircraft, drag divergence is delayed to higher Mach numbers. [1]

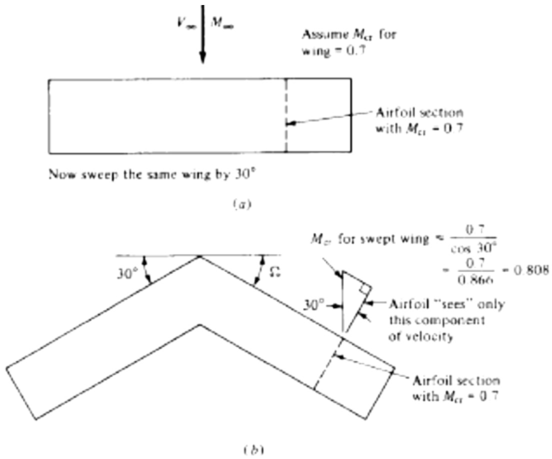

Fig.5: Effect of swept wing on critical Mach number.

In real life, the flow over the swept wing is a fairly complex three-dimensional flow, and to say that the airfoil sees only the component normal to the leading edge is a sweeping simplification. However, it leads to a good rule of thumb. If Q is the sweep angle, the actual critical Mach number for the swept wing is bracketed by:

$$M_{cr} for\ airfoil < actual\ M_{cr}\ for\ swept\ wing < \frac{M_{cr}\ for\ airfoil}{cos\Omega}$$

4. AIRPLANE DESIGN

A CAD model of RC airplane is designed in SolidWorks. The following Model is a rendered model of Airplane.

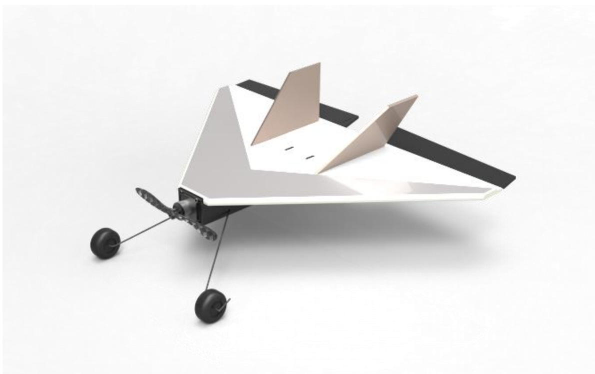

Fig 6: CAD model of delta wing airplane

4.1 Dimension layout:

The main delta plan form dimensions are shown in bellow:

4.2 Simulation of flight:

The flight simulation gives a good perspective meshing and fluid flow around the wing. In figure 7 shows the pressure distribution around the delta wings. The aerodynamic forces are due to positive and negative pressure gradients that are shown in pressure contours. In figure 8 shows that the delta wing pulls the stream line toward and lessen the mean of pressure under wing. However this will pushes the flow stream and increases the mean pressure on the wing. If the pressure difference decreases the lift will also be decreases.

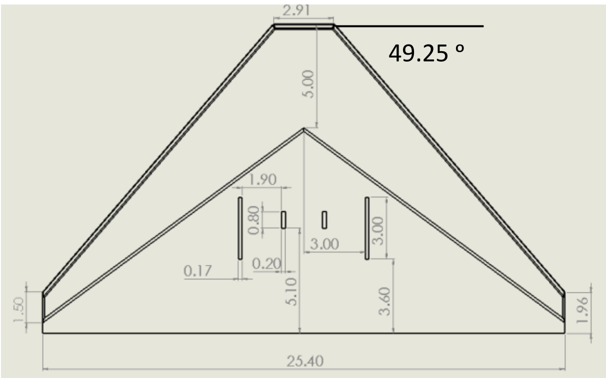

Fig 7: Delta plan form dimensions in inches.

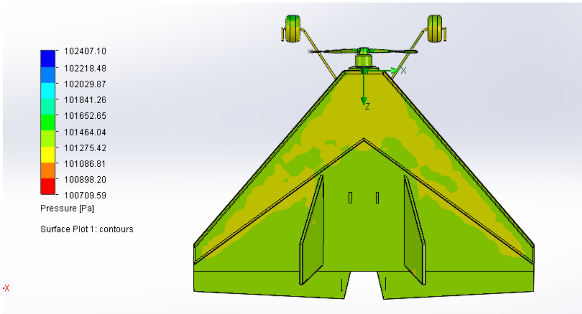

Fig 8 a: Pressure at upper surface of the wing.

The lower surface pressure distribution shows higher pressure on lower portion of the wing. So lift will be generating.

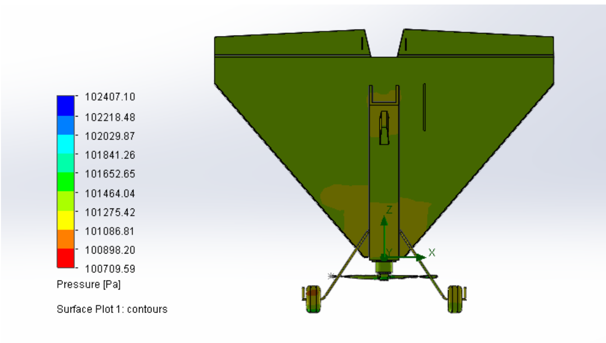

Fig 8 b: Pressure at lower surface of the wing.

4.4 Design parameter

The shape of the wing is semi airfoil shape like it has a round leading edge but then it becomes flat shape. The first step in plane designing is to determine wing area. This portions plays an important role in payload endurance threshold. On the other hand wing must cover all parts of the air craft. According to the model weight, wing span and loading value are selected. The wing area can be calculated using equation (2)

$$b = \sqrt{AR \times S} \qquad (2)$$

Here b is the wing span, AR is the aspect ratio and S is the wing area. Fling wings do not have conventional vertical and horizontal tail. In order to secure the stability requirements the wing has backward sweep, negative twist, and dihedral. To compensate longitudinal stability reflex sections are used. Elevators are used to this end. Also to increase roll and yaw stability two winglets are added to the wing's middle sections. This wing shape selection affects all other behavior of plane.

Normally, the RC Airplane center of gravity or cg of the aircraft is to be located at 25% or 0.25c (of the mean aerodynamic chord). For the RC airplane, a vertical line is marked on the mean aerodynamic chord. At 25% or 0.25c of the mean aerodynamic chord, a horizontal line is marked on the wing. At the center point of the joint of two wings a straight vertical line is marked. The two lines will intersect each other at a point. That point is the reference cg point. An RC Airplane can be either nose heavy or tail heavy. Now the reference cg point is obtained. Then the airplane is checked if the cg of airplane is at the reference cg point or is it nose heavy or tail heavy. To do this, two people are required. One person stands on each side of the wing. Wing is lifted with a single finger (don't lift up/touch any other part of the aircraft during this check) along the reference vertical line which passes through the reference cg point. If the airplane is nose heavy or tail heavy it will automatically move in either direction. If airplane not at the cg point add ballast either to the nose or tail until the cg point is reached.

5. CONSTRUCTION

Necessary equipment's:

- Depron foam
- Brushless DC motor
- Electronic Speed Controller (ESC)
- Servo motor
- Transmitter
- Receiver
- Pushrod
- Hot glue
- Li-Po battery

The Depron board was used for the construction of the airplane body. First the CAD model was drawn in SolidWorks software and considering the same scale of designed model in CAD layout the Depron board was cut into desired shape for making wing, radar, elevator and fuselage. Then the full body was assembled and full airframe was constructed. In the following figure constructed body has been shown:

5.1. Electronic parts setup

The main concern of the electric circuit is to rotate the propeller. The propeller (8*4.5) is connected with the BLDC motor. The motor is also connected with the ESC (Electronic Speed Controller) which will take power from Lithium-polymer battery and give a DC voltage to control the BLDC motor. The 500 mah Battery will provide maximum current of (.5 Amp. Hour*20 C* 3 Cell) 30 Ampere. The maximum working condition of ESC under 30A. So, it is reliable. Each servo is contained a pushrod which is connected to the control surface. So, two servo is connected to the Receiver from which it will get radio frequency signal from the transmitter. A receiver will connect two servos and the ESC. Operator can supply frequency signal to the receiver through transmitter, than the frequency signal will convert to desired electronic signal for operating the aircraft. The circuit setup was showed in figure

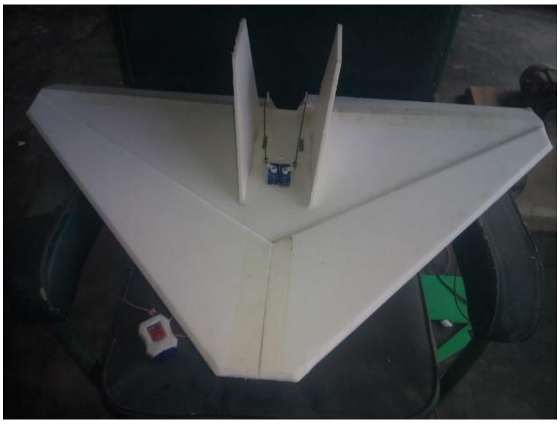

Fig 9: Full constructed airframe

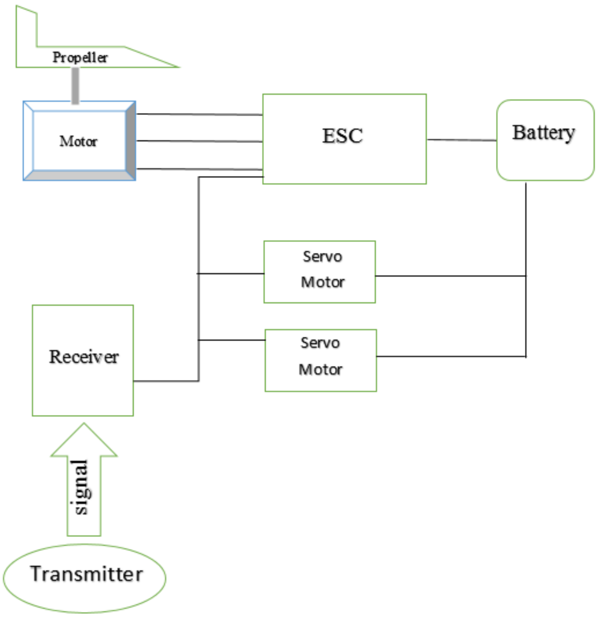

Fig 10: Circuit diagram of electronic connection.

Fig 11: Full construction after electronic connection

6. CALCULATION & PARTS RATING

Wing area, S= 235.4 in^2
Aspect ratio (AR) = 2.74
Total weight of the model = 300 grams
Motor power=245 watt
Propeller size= 8 inches
Propeller pitch = 4.5 inches
Battery = 500 mah 20C Li-Po
Maximum speed produced by motor = 15540 rpm
Theoretical maximum velocity can be produced by propeller =29.6 m/s

7. TESTING

The model having low weight and the transmitter and receiver is employed to the airplane. The transmitter works well and different control surfaces are checked by transmitting the signal. Before flight the above features should be checked.

Several tests has been conducted. At first time it does not work so well because of misbalancing of landing gear. But after balancing with straight wires, it flies. Only some vertical distance has been covered during flight because of safety of the model since the model having light weight and the range of the transmitter.

8. TESTING RESULTS

Test results are as follows:

- Model showed good maneuverability and acceptable stability.
- Maximum speed was about 15 m/s
- The flying time was about 3 minutes.
- The response time is not so good but better transmitter and receiver can minimize the problem.

Since the airframe is made of hand cut so making a uniform wing is little bit tough work. For this project total five model was constructed for better performance. But uniform cutting process can minimize the problem.

9. ACKOWLEDGEMENT

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11. NOMENCLATURE

Symbol	Meaning	Units
M_∞	Mach number of free stream air	Dimensionless
M_{cr}	Critical Mach number	Dimensionless
ρ	Density	kg/m^3
V	Velocity	m/s
p	pressure	Pa
b	Wing span length	m
S	Wing area	m^2
AR	Aspect ratio	Dimensionless