

# Radio Controlled Airplane

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**Abstract**— The motive of creating this paper is to encourage all the fellow students in the field of Aerodynamics, which is best achieved by creating an aerodynamic model. In this research paper we have tried to include all the essential data required to build a flying model which we hope will help students as the guide to complete their model. This paper concentrates mainly three aspects of aircraft modeling which are as follows: - Designing, Construction, Electronics.

**Key words:** Profile Drag, Skin Friction Drag, Pressure Drag

### I. INTRODUCTION

In today's modern world Airplanes are nothing new to we humans, we have at some point of time in our life seen or may have experienced an airplane flying. But this idea of creating a mechanism to make humans fly had started rising into human brains many centuries ago. Many famous stories of the ancient times involve the idea flying, such as Greek legend of Icarus & Daedalus, and the famous Indian epic RAMAYANA involves a flying vehicle called 'Vimana'. Also one of the great thinkers of all times Leonardo da Vinci in 1502 designed a man powered aircraft by researching over wing design of birds. There were many such thinkers who contributed in the field of Aerodynamics such as Sir George Cayley, Otto Lilienthal, Lawrence Hargrave and many more. The Wright Brothers, Orville and Wilbur American Inventors were credited with inventing the first successful airplane and making the first sustained & controlled heavier than air powered flight in the year 1905.

The radio controlled airplane were firstly introduced for research purpose, the miniature planes were first constructed as a study model of the airplanes under research to study the forces acting on the newly designed models and the design was edited to extract the desired result. During the period of World War-II the R/C Airplanes were used for target practice of army planes. We should understand that the aerodynamic study of the full scale Airplanes and the R/C Airplanes are identical. The only difference between the full scale Airplane and R/C Airplanes are the wing loading, Reynolds Number and the moments of inertia which are explained further.

R/C models typically have wing loadings of 1-3 lb/ft<sup>2</sup> whereas the full scale airplanes are greater than 10. The R/C model will typically have Reynolds Numbers less than 500,000 whereas Full scale airplanes are greater than one million Reynolds Number. The R/C model will have much smaller moments of inertia than the full scale airplane.

### II. VARIOUS FORCES ACTING ON AIRPLANE (6)

#### A. Lift:

The aerodynamic force resolved in the direction normal to the free stream due to the integrated effect of the static pressures acting normal to the surfaces.

#### B. Drag:

The aerodynamic force resolved in the direction parallel to the free stream due to (1) viscous shearing stresses, (2) integrated effect of the static pressures acting normal to the surfaces and (3) the influence of the trailing vortices on the aerodynamic center of the body.

#### C. INVISCID Drag-Due-To-Lift:

Usually called induced drag. The drag that results from the influence of trailing vortices (shed downstream of a lifting surface of finite aspect ratio) on the wing aerodynamic center. The influence is an impressed downwash at the wing aerodynamic center which induces a downward incline to the local flow. (Note: it is present in the absence of viscosity)

#### D. Viscous Drag-Due-To-Lift:

The drag that results due to the integrated effect of the static pressure acting normal to a surface resolved in the drag direction when an airfoil angle-of-attack is increased to generate lift. (Note: it is present without vortices)

#### E. Skin Friction Drag:

The drag on a body resulting from viscous shearing stress over its wetted surface.

#### F. Pressure Drag:

Sometimes called form drag. The drag on a body resulting from the integrated effect of the static pressure acting normal to its surface resolved in the drag direction.

#### G. Interference Drag:

The increment in drag from bringing two bodies in proximity to each other. For example, the total drag of a wing-fuselage combination will usually be greater than the sum of the wing drag and fuselage drag independent of one another.

#### H. Profile Drag:

Usually taken to mean the sum of the skin friction drag and the pressure drag for a two-dimensional airfoil.

#### I. Trim Drag:

The increment in drag resulting from the aerodynamic forces required to trim the aircraft about its center of gravity. Usually this takes the form of added drag-due-to-lift on the horizontal tail.

#### J. Base Drag:

The specific contribution to the pressure drag attributed to a separated boundary layer acting on an aft facing surface.

#### K. Wave Drag:

Limited to supersonic flow. This drag is a pressure drag resulting from noncancelling static pressure components on either side of shock wave acting on the surface of the body from which the wave is emanating.

**L. Cooling Drag:**

The drag resulting from the momentum lost by the air that passes through the power plant installation (ie; heat exchanger) for purposes of cooling the engine, oil and etc.

**M. Ram Drag:**

The drag resulting from the momentum lost by the air as it slows down to enter an inlet.

**III. DESIGNING**

**A. Important Terms:**

**1) Wing Loading:**

According to aerodynamics, Wing Loading is said to be the amount of load carried by per unit of wing area. Suppose a fuselage is attached with a wing of smaller area then the amount of load carried by per unit of wing area in more which causes unstable flight, on the other hand if larger wing is used the distribution of the load along the surface of the wing area will be less and we can achieve much stable flight. For model aircraft, Wing Loading is expressed ounce per square foot (oz/ft<sup>2</sup>).

**2) Formula:**

$$\text{Wing Loading (oz/sq.ft)} = \text{Weight (oz)} / \text{Wingarea(ft)}$$

**3) Reynolds Number:**

When an object in our case wing passes through the air, the air molecules stick to the surface of the wings called as Boundary layer. When the air flows further its molecules interact with this layer and cause various effects on the wings. The Reynolds Number a dimensionless number used in fluid mechanics to indicate whether effect of air flow is steady or turbulent. It is defined as the ratio of the inertia forces to the viscous forces.

**4) Formula:**

$$Re = \rho VL / \mu$$

Where  $\rho$ =density of the fluid,  
 $V$ =velocity of the fluid,  
 $\mu$ =viscosity of fluid,  
 $L$ =length or diameter of the fluid.

**B. Wings:**

Wing is the most important part of the plane which provides lift, which causes the plane to fly. Wings are of the following three types:

- Monoplane: This type of wings is most popularly used over multiplane configuration because the adjacently placed wings generate more drag and reduce efficiency.
- Biplane: An airplane having two pairs of wings fixed at different levels such that one wing is placed above and one below the fuselage. It provides 20% more lift than the monoplane but increases the weight of the plane and generates extra drag.
- Triplane: An airplane having two pairs of wings fixed at different levels such that one wing is placed above, one at the centre and one below the fuselage. Causes generation of excess drag and increase in weight of the plane

Position of the wings on the fuselage:

**1) Low wing:**

The wing is attached to the lower part of the fuselage.

**a) Effects:**

- It can carry more loads.
- Due to equal lift distribution from tip to tip, the speed will be more.
- The simple structure provides more maneuverability

**2) High wing:**

The wing is attached to the higher portion of the fuselage

**a) Effects:**

- It gives stable flight.
- Speed is comparatively less than the low wing.
- It is not more aerobatic.

**3) Mid wing:**

The wings are connected to the middle part of the fuselage

**a) Effects:**

- The airplane structure is heavier.
- Flight is not so stable.
- Structure provides adequate maneuverability

**C. Airfoil:**

An airplane wing has a special shape called an airfoil. As a wing moves through air, the air is split and passes above and below the wing. The wing's upper or the lower surface is shaped in a form of a curve depending on the requirement of the model. This curve shape causes the air to rushing over it to speeds up and stretches out(3). This decreases the air pressure over the curved part of the wing.

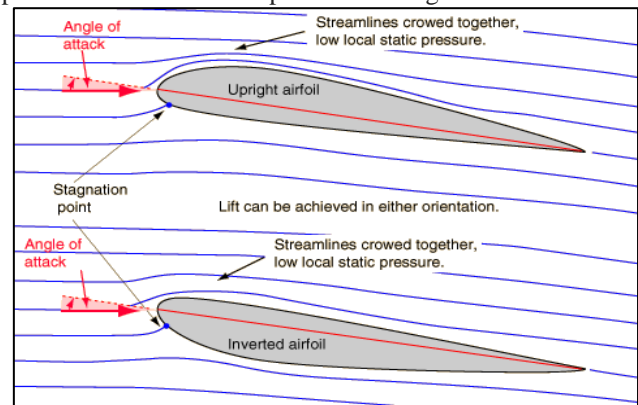


Fig. 1: Angle of attack against the upright & inverted airfoil

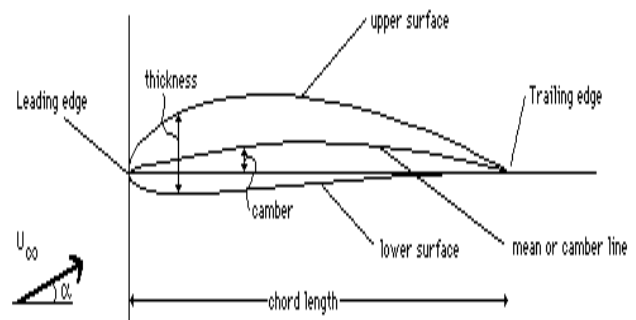


Fig. 2: Measurements of a airfoil

**D. Dihedral Angle:**

The angle formed between the imaginary x-y axis and the wing at the centre chord is called as dihedral angle. For the purpose of aircraft symmetry, both right and left sections of a wing must have the same dihedral angle.

The purpose of dihedral is to provide stability during flight. If the wing tip is higher than the x-y plane, the angle is called positive dihedral or simply dihedral, but

when the wing tip is lower than the x-y plane, the angle is called negative dihedral or anhedral.

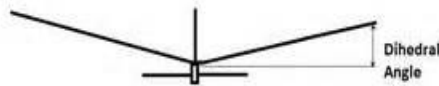


Fig. 3: Dihedral Angle

#### E. Aspect Ratio:

Aspect ratio indicates the all-round performance of the wings. It is a measure of how long and slender the wings are. For "high" aspect ratio aircraft wing indicates long, narrow wings, whereas a "low" aspect ratio wing indicates short and stubby. The wings with high aspect ratio produce more lift as the angle of attack increases than the low aspect ratio.

$$\text{Aspect ratio} = \text{wing span}^2 / \text{wing area}$$

#### F. Lift & Drag coefficient:

The lift force is dependent on the density of the air  $\rho$ , the airspeed  $V$ , the wing's Lift Coefficient and the wing's area according to the formula:

$$\text{Lift Force} = 0.5 * \rho * V^2 * \text{Wing's Lift Coefficient} * \text{Wing's Area (10)}$$

The Wing's Lift Coefficient is a dimensionless number that depends on the airfoil type, the wing's aspect ratio (AR), Reynolds Number (Re) and is proportional to the angle of attack ( $\alpha$ ) before reaching the stall angle. However, the wing's generation of lift also produces Induced Drag, which along with Parasitic Drag are forces that oppose the aircraft's motion through the air. One may also say that Induced Drag is the price we pay for getting lift. Induced Drag is also dependent on the density of the air  $\rho$ , the airspeed  $V$ , the wing's Drag Coefficient and the wing's area according to the formula:

$$\text{Drag Force} = 0.5 * \rho * V^2 * \text{Wing's Drag Coefficient} * \text{Wing's Area (10)}$$

The Wing's Drag Coefficient is a dimensionless number that depends on the airfoil type, the wing's aspect ratio (AR), the shape of the wing tips, Reynolds Number (Re) and the angle of attack ( $\alpha$ ). The relation between lift and drag is called the Lift to Drag ratio (L/D) and is obtained by dividing the Lift Coefficient by the Drag Coefficient. The characteristics of any particular airfoil may be represented by graphs showing the amount of lift and drag obtained at various angles of attack as well as the Lift/Drag ratio. The same airfoil has different Lift and Drag Coefficients at different Reynolds Numbers as shown in the graphs below(10):

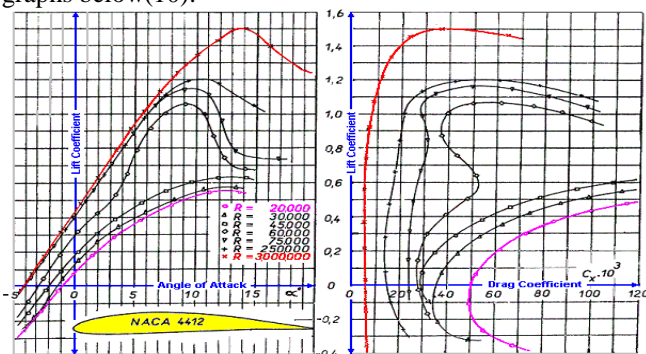


Fig. 4: Lift coefficient v/s Angle of attack

Fig. 5: Lift coefficient v/s Drag coefficient

#### G. Tail(11)

##### 1) Conventional:

This configuration includes one horizontal tail (two left and right sections); located on the tail of fuselage; and one vertical tail (one section); located on top of the tail of fuselage. Both horizontal and vertical tails are located and mounted to the tail of fuselage

##### 2) T-tail:

A T-tail is an aft tail configuration that looks like the letter "T"; which implies the vertical tail is located on top of the horizontal tail

##### 3) Cruciform:

The cruciform; as the name implies; is a combination of horizontal tail and vertical tail such that it looks like a cross or "+" sign. This means that the horizontal tail is installed at almost the middle of the vertical tail. The location of the horizontal tail (i.e. its height relative to the fuselage) must be carefully determined such that the deep stall does not occur and at the same time, the vertical tail does not get too heavy.

##### 4) H-tail:

The H-tail, as the name implies, looks like the letter "H". H-tail comprised of one horizontal tail in between two vertical tails

##### 5) V-tail:

As the name implies, the V-tail configuration has two sections, which forms a shape that looks like the letter "V". In another word, a V-tail is similar to a horizontal tail with high anhedral angle and without any vertical tail. Two sections of a V-tail act as both horizontal and vertical tails.

##### 6) Y-tail:

The Y-tail is an extension to the V-tail, since it has an extra surface located under the aft fuselage. The lower section plays the role of vertical tail, while the two upper sections play the role of the horizontal tail. Therefore, the lower surface has rudder, and the control surface of the upper section plays the role of the elevator.

##### 7) Twin Vertical Tail:

A twin vertical tail configuration has a regular horizontal tail, but two separate and often parallel vertical tails. The twin vertical tail largely improves the directional controllability of an aircraft.

##### 8) Boom-Mounted:

In this case, two booms and install the tail at the end of the booms. This option in turn, allows using a shorter fuselage, but overall aircraft weight would be slightly heavier.

##### 9) Inverted V-Tail:

An inverted V-tail usually has the surfaces mounted a single boom, which places the surfaces in danger when close to the ground. Inverted V-tails tend to have worse steady state performance in turns, plus they can be very tricky from a structural standpoint. Inverted V-tail is slightly better for jaw control in coordinated turn.

##### 10) Triple Tail:

A variation on the twin tail, it has three vertical stabilizers. An example of this configuration is the Lockheed Constellation on the Constellation it was done to give the airplane maximum vertical stabilizer area.

##### 11) Boom-mounted Inverted V tail:

The Inverted V allows for twin tail boom design, allowing for a large diameter prop. It also raises the ground clearance of the tail on landing and takeoff.

12) Ring tail:

The aerodynamics of the ring is unusual. All of the air that flows through the inside of the ring is deflected to the angle of the ring. But the outside of the ring acts like a giant wing tip, spilling much of the air, rather than deflecting it. I had to make the ring large enough in diameter so plenty of air would flow through it. A ring is very stall resistant, allowing unusually high angles of attack, but has more drag than a conventional tail.

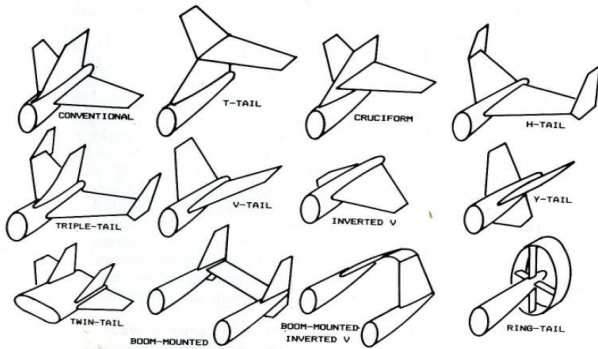


Fig. 6: Different types of tail

H. Fuselage:

Fuselage is the main structural element of the RC Airplane or the body of the RC Airplane. The Wing, Horizontal and Vertical Tail are connected to the fuselage. The Engine is also mounted to the fuselage. The fuselage is made up of bulk-heads. The bulk-heads are structural members which give strength and rigidity to the fuselage, support load and weight of the RC Airplane(3). The Engine bulk-head is made relatively stronger as compared to other bulk-heads of RC Airplane fuselage because it carries the load of the engine as well as encounters vibrations during engine operation so it must be strong to resist all the loads. The nose gear and main landing gear are also connected to the fuselage. The fuselage also houses all the electronic components necessary for RC Airplane flight including ESC (electronic speed controller) in case of electric RC Airplane, Receiver, Servos, Batteries and fuel tank in case of gas powered RC Airplane. External or internal payloads are also carried inside the fuselage. The fuselage can be used to connect an external camera for example or to carry some payload inside the RC Airplane.

IV. ELECTRONICS

A. Selection of Propeller & Motor(12)

There are bunch of propellers and motors available in market. We have to choose one of them as per our need. So first we need to understand propeller. Every propeller is identified by certain number. First number represents diameter of propeller whereas second is Pitch. Pitch is distance covered by propeller in one revolution. Propeller with High Pitch travels more distance & makes plane faster. If slower speed is required, we should choose propeller with low pitch and larger diameter which gives more power to pull the airplane forward.

Motor has KV ratings which stand for RPM per volt.

E.g.1800 KV Motor with 12V will give 21,600RPM. Combination of Motor and Propeller depend upon following factors:-

- 1) Weight of the plane.
- 2) Available ground clearance.
- 3) The Wingspan and the wing area of the plane.

Minimum Speed (stall speed) required by plane in mph is approximately equal to four times the square root of the wing loading in ounces per square foot and max speed is of 2 or 3 times greater than stall speed.

Following table gives Thrust, pitch speed etc. for various props for I/P of 11V:-

Prop Size	Input Voltage	Motor Amps	Watts Input	Prop RPM	Pitch Speed	Thrust Grams	Thrust Ounces	Thrust Eff. Grams/W
4.75x4.25-E	11.1	4.47	49.6	14,456	58.2	188	6.63	3.79
4.75x4.75-E	11.1	4.82	53.5	14,253	64.1	183	6.46	3.42
4.75x5.5-E	11.1	5.56	61.7	13,840	72.1	170	6.00	2.75
5x5-E	11.1	5.63	62.4	13,806	65.4	189	6.67	3.03
5.25x4.75-E	11.1	6.12	67.9	13,517	60.8	263	9.28	3.87
5.5x4.5-E	11.1	6.33	70.2	13,393	57.1	270	9.52	3.84
6x4-E	11.1	6.98	77.5	13,070	49.5	359	12.66	4.63
6x5.5-E	11.1	8.88	98.6	12,060	62.8	328	11.57	3.33
7x4-SF	11.1	10.30	114.3	11,308	42.8	544	19.19	4.76
5x3x3-DD	11.1	3.97	44.1	14,749	41.9	245	8.64	5.56
5x4.3-DD	11.1	4.15	46.0	14,647	59.6	264	9.31	5.74
6x3-DD	11.1	4.98	55.2	14,167	40.2	343	12.10	6.21
6x3x3-DD	11.1	5.61	62.3	13,813	39.2	358	12.63	5.74
7x3.5-DD	11.1	6.81	75.6	13,181	43.7	437	15.41	5.78
7x3.5x3-DD	11.1	8.17	90.7	12,430	41.2	486	17.14	5.36

Fig. 7: Table of propellers for different parameters

B. ESC:

Electronic speed control converts DC power coming from battery to AC power going to Motor. It is used to control RC Plane's speed and it also provides power to Rx from battery with the help of BEC. (Battery Elimination Circuit)

What to look in ESC:-

- 1) Every ESC has power limits. Motor pulls peak current at full throttle, so always choose ESC with current rating 10-20% higher than Motor.
- 2) Make sure it handles same no. of cells that your motor handle

C. Battery:

LiPo batteries are used to power RC Planes. We need to consider following factors for choosing battery:-

- It has to put out the correct voltage.
- It has to put out enough current to permit the motor to carry the plane for the required flight time.
- It has to be light enough that the plane can carry the weight.

D. Servo:

Servos, these are the little motors that move the control surfaces on RC planes. Servos are made up of small brush motors, a potentiometer and a couple of gears. Potentiometer regulates the movement of motor which allows servo to move exact amount of grease. Servo can move 180° mechanically, but under its own power it can only move 90°. (13)

There are two main types of servos as following:-

- 1) Analog Servo
- 2) Digital Servo

They are both the same with all the physical parts except for the digital servos have a microprocessor that takes I/P from receiver. It makes servos more accurate and

faster because they consume power, which is not significant in the RC Plane. Servos are further classified as a metal servo or of nylon. Metal gear servos are much stronger and they don't strip easily. The next classification can be made depending upon its weights, but 9 grams servos are most commonly used. Most servos run off on 3 to 5 volts, but some high voltage servos require 7.5 volt. These are used for larger planes which need higher torque.

#### E. R\C Control System:

Radio Tx\Rx are basically used to control all the possible functions on a plane. Transmitter transmits control information to Plane. Any basic Transmitter must have at least 4 channels for Throttle, Elevator, Aileron, Rudders. Radio operates on different frequencies, but most commonly used is 2.4GHz. Receiver takes signal from Transmitter. Channels on Receiver goes in order by first battery, throttle, Aileron, Elevator, Rudder. Receiver gets its power from ESC. ESC is plugged into Throttle port; Receiver gets power from this port. We can place Receiver on top or bottom or any of the sides of plane just don't put it too close to ESC, because it can interfere signals going to ESC.

#### V. CONCLUSION

Hence using this paper we can successfully make a self-made R/C Airplane. Since the papers include most of the Designing as well as Electronic aspects it may prove to be very useful for the beginners.

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