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Design And Simulation Of Rc Cargo Airplane

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Abstract : *The aircraft was first invented by wright brothers. In Previous 10 years, number of passengers death per kilometre increases. To overcome these problems, new innovation was done by scientist which was unmanned aerial vehicle (UAV). UAV is used in many sector such as military, surveillance of geographical boundary, agricultural, cargo transportation. In India UAV is refused in public sector, but most probably it is used in military because there is no human interference. So there is no risk to soldier life. This was achieved by choosing the optimum values of fuselage length, wingspan, elevator, rudder dimension and all up weight determined by a series of iterative analysis. The modelling can be done using the software Solid Works. The analysis of determining the parameters of the plane can be done using XFLR-5. This can be also confirmed by the method of computational fluid dynamics using commercial software ANSYS.*

Keywords : *RC plane, Fuselage, Wingspan, Elevator, Rudder, Drag Lift, Stall and angle of attack.*

I. INTRODUCTION

The main aim of this project was to design, analyze and build an RC plane. This involves understanding the various aerodynamic forces and moments acting on the plane, choosing the right motors, controllers for its operations and hence making it fly. Hence this project involved optimization of various parameters for an enhanced flight. In order to achieve the stated objective, extensive literature review was done in determining the various parameters for building of the plane. All authors together in suggest development of a Canard type aircraft, with the mission of aerial reconnaissance and surveillance. Provide insight into flapping flight configuration that provided an insight into improved aerodynamic performance and hover capabilities. Also provide a review of state of art with respect micro and nano aerial vehicles, which helped better understanding of different design and engineering principles for such vehicles. Based on all the literature review and available knowledge, it was decided to systematically design, analyze and build an RC plane. In addition it was decided to develop such a plane, to maximize the aspect ratio, minimize the wing loading and optimize the weight. Basic terms like lift coefficient, tip, root chord, taper ratio etc help understand the aerodynamics of flight while movement of air over the airfoil help understand the behavior of flight in air. Keeping these considerations in mind the design and optimization were done.The aim of this paper is therefore to explain the systematic methodology followed for designing, analyzing and building the RC plane including details of optimization. The following are the major steps in this process:•

- Selecting various design targets, Selecting the type of geometry.
- Optimization of parameters to obtain the best performance.
- Determining the stress points, critical points on the wing and fuselage (for example – Centre of Gravity of the plane).

- Designing the fuselage, wing, elevator etc (using the appropriate airfoil).
- Analyzing the structure for its parameters, Analyze and reiterate as appropriate

1.1. Objective of Study : The objective of this study is designed for compressed aircraft and lift the maximum payload with utilizing minimum power within given take off & landing distance. As many conventional UAVs are working on maximum power. So we will increase the efficiency of aircraft, speed of aircraft, and performance of aircraft by using minimum power.

1.2. Problem Statement : In India aero dynamics is not known by everyone but having courage, to learn problem faced by people especially those who are protecting the boundary of our nation. Our main aim is to built an aircraft model that can solve such type of problem. Problem generated without human interference which are solved by UAV are as follows:- 1] In agricultural sector, monitoring livestock, water level, crops etc.

2] Delivery of food at flooded area. 3] Surveillance of geometrical boundary.

4] Fire fighting. Aircraft will lift highest payload within 1000 watt in given take off distance and landing distance which are 100 Ft. and 400 Ft. respectively

1.3. Constraints and Requirements : As per the demand & requirements everyone wants effective and faster RC plane, while hunting the requirement we found that electric motor or engine can be used. Here the main task is selection of motor to satisfy our requirements. For power source, battery is required. So we selected cell battery as it was one of our first constrained. Here we focused on the geometrical appearance of RC plane, Thus not manufactured the huge plane because of capability of selected motor. Every time trial and error method cannot be used because every part is costly so we must have proper justification. Then we moved towards the selection of suitable airfoil which is essential for plane. Here performance and efficiency of RC plane, depends upon the selection of motor and airfoil. We know that RC plane lifted Avg. of 8- 13 Kg in India. So we decided to lift the payload as 10 Kg as per the theoretical calculation. Here, second main constraint is balancing the RC plane without GYROSCOPE. Conventional RC plane carries the same payload but for invention purpose we reduce the power upto 1000 watt. Here becomes the big challenge for us that to lift maximum payload so that maximum power is used but in our aircraft more payload is lifted by less power.

1.4. Objectives : 1] To designed unmanned aerial vehicle to carry maximum payload using 1000 watts.

2] Balance the RC plane without using gyroscope.

3] Utilizing the aero dynamic knowledge to build the effective cargo plane.

4] Reducing the drag of RC plane to make more efficient RC plane.

5] Create maximum power output using limited power less than 1000 watts.

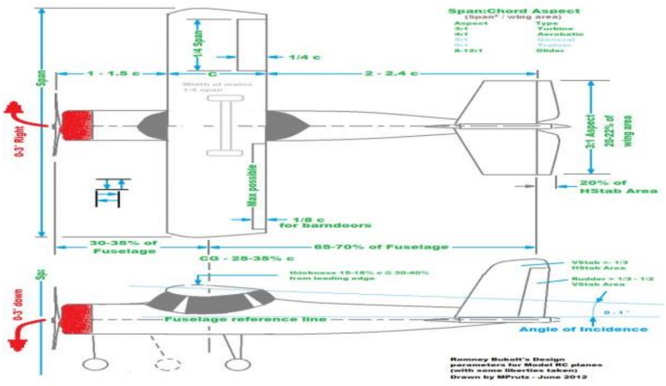


Fig. 1 basic configuration of the RC.

II. METHODOLOGY

2.1. Material Selection : In every product material plays essential role. According to our objective we can make lighter RC plane, so we have to select lighter material. As we know wood having less density than metals but does not sustain in every weather condition. To overcome these we are using less density, high strength and maximum durable matrial. We found material are as follows: 1. Balsa :- density 190 Kg/m3 ,2. Aero ply :- 26 Kg/m3,3. Bass wood :- 190 Kg/m3

We study some reference paper of UAV(Unmanned Aerial vehicle) and improve the results and by considering result we come to following methodology-

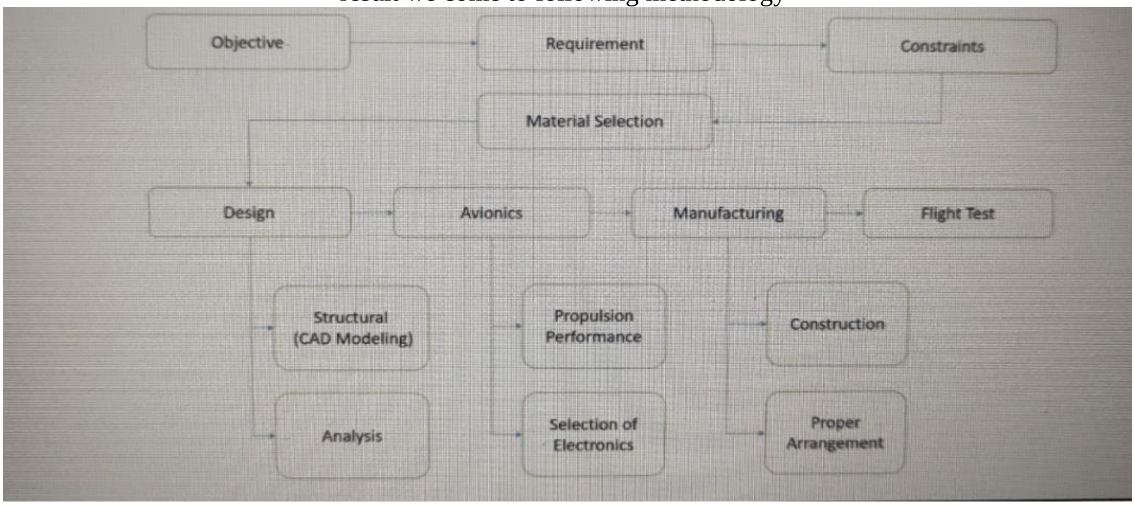


Fig. 2 Methadology

2.2. Design And Analysis : Design plays an important role in project. In design, we used the solidworks, Ansys & XFLR softwares for primary calculations and analysis. As per the theoretical calculations and assumptions, we focused on the CAD model and XFLR's solution. If theoretical value and software solution are approximately equal to each other then it goes in a right way. After this, we go for analysis of each part. If the design is safe then we follow the next step which is manufacturing. If the design is not safe then we go to second iteration till the design is safe. Here we successfully ended with design phase.

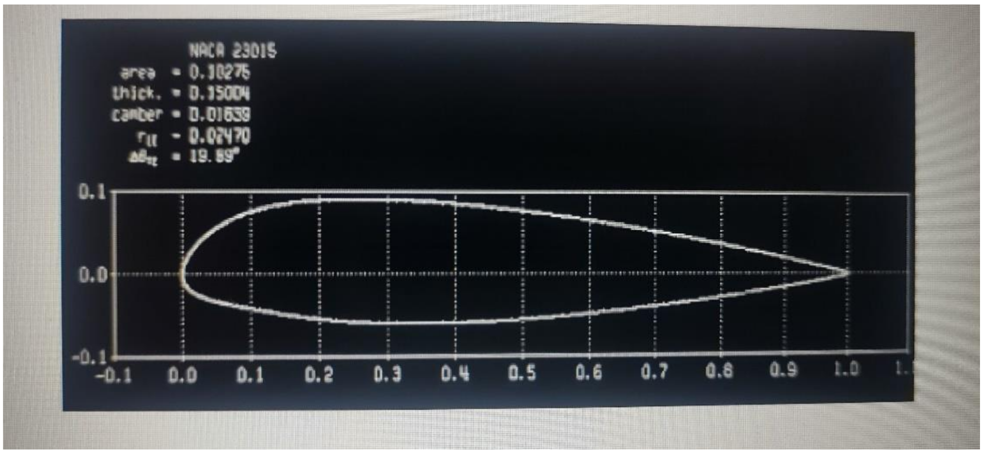


Fig. 3 NACA 23015 Airfoil

2.3. Design Sensitivity : Sensitivity of individual components in model with respective changes and design parameter are mandatory in order to facilitate structural modifications. Wing layout is an important design variable where its span is inversely proportional to its chord length. Other variables like horizontal tail and vertical tail parameters are dependent on wing area. A secondary design variable like fuselage fineness ratio which is dependent on fuselage diameter is commonly picked between 4 and 8. This makes fuselage length dominant over fuselage diameter.For wing, as the parameters are compared for Arsya20(Interpolated Airfoil) and S1223 airfoils, it has come to know that S1223 gives a maximum Cl and thus greater lift, where as Arsya20 gives better stability and has lower Cd. For the same purpose, stability is achieved by installing S1223 at the root chord and Arsya20 at the tip chord. For Elevator, the reason NACA 0012 airfoil is chosen is to counter balance the moments of elevator and wing, as the wing gives positive moment while NACA 0012 helps us to get negative moment. As we compare the data of Arsya20 and S1223 airfoils with the other 11 airfoils, it has been seen that S1223 gives better CL.

2.4. Drag Analysis : The 3D drag polar analysis on an airplane can be approximated using equation-

$$c_D = C_D \min + k' C_L^2 + k''(c_L - C_{L\min})^2$$

This equation is a summation of pressure and skin friction drag contributions from all airplane components, k' is the inviscid induced drag factor, CL is the coefficient of lift at a given angle of attack, k'' is the viscous induced drag factor and minimum coefficient of lift. Cdmin is calculated by summing the contributions of each component as calculated with equation, $C_D \min = \frac{FF \times C_f \times Swetted}{S_{Plattform}}$

In this equation, 'FF' is the form factor, 'Cf' is the skin friction coefficient and can be found by using graph of skin friction coefficient versus Reynolds Number, Swetted is the wetted surface area and Splanform describe the planform area of the components. Below table shows these values computed at an anticipated level flight velocity of 40 feet per second. Also piece wise 3D drag contributions of each aircraft component to the overall aircraft. (Note: Reference White paper of Dr. Leland M. Nicolai, Lockheed Martin Aeronautical Company)

Then, the inviscid induced drag factor K' is calculated with equation- $k' = \frac{1}{\pi ARe}$.

In the above equation, AR represents the wing aspect ratio and e is the wingspan efficiency. K', AR, and e were calculated to be 0.0180, 4.68 and 0.98 respectively. Then the viscous induced drag factor k'' is determined as the slope of the nearly linear relation shown below. CLmin is computed as 0.6 at a Reynolds number 215000 for the wing and k'' is found to be equal to 0.0028. Finally these values can be substituted back into equation 1 to obtain the airplanes 3D drag coefficient of all air foil lift coefficients.

2.5. Power Plant :

Table 1. Parts and Specifications

Sr No	Component	Manufacturer	Specification	QTY
1	B.L.D.C motor	T- Motors U10 plus	Rpm/volt : 170kv	1
2	Speed controller	Flame 80A HV	Operating volt: 2-6 Lipo,80A	1
3	LiPo battery	Tattu	Tattu 6S/22.2V, 4500mAh	1
4	Propeller	T-motors	30''X10.5''	1
5	Transmitter & receiver	Futaba	10JA 2.4GHz 10-Channel S/FHSS, R3008SB Reciever	1
6	Servo	Turnigy – TS-910 Avionics	Torque - 270 oz/inch Speed – 0.16sec/60 degree Torque – 113.87 oz/inch Speed – 0.15sec/60degree	3 3
7	SAE power limiter	Neu motors	1000 watts power limiter	1

2.6. Take-Off Constraints : It the requirements specify a maximum take-off length the takeoff curve give the allowed variation of T/W vs T/W for which this requirement is exactly satisfied. $\frac{T}{W} = \left[\frac{1.21}{g p_\infty (cl) ma\varkappa S_g}\right] \frac{w}{s}$

2.7. Landing Constraints : If the requirements specify a maximum landing length, then landing curve represents this constraint. Values of W/s to the left of the vertical line will satisfy the constraint by resulting in a landing distance smaller than required value. So, the area to the left of landing curve is 'allowable' from the point of view of the landing constraint.

2.8.Sustained Level Turn : If the requirements specify a sustained level turn with a given load factor at a given altitude and speed then this parabolic curve represents this constraint. Values of T/W above this curve satisfy the sustained turn requirements. The area above this curve is 'allowable' from the point of view of the sustained turning requirement.

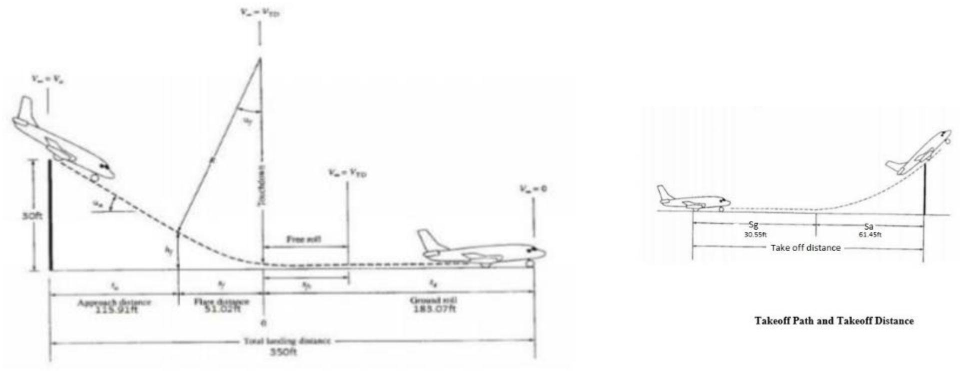
Take-off curve, Landing curve and Parabolic Curve represents only constraints, the area in figure that is common to three allowable areas is the shaded identified as Solution Space. An RC Plane with any combination of T/W and W/s that falls within this Solution Space will satisfy the constraints imposed by the requirements. Hence, we pick up a design point with relatively low T/W which is in the Solution Space, so that our aircraft design is not overpowered.

2.9. Loads and Environment Assumption load Derivation the theory behind the loading prediction for the landing gear is impulse momentum formula given by $f\int_0^t dt = m\int_1^2 dV$
Assuming that the initial Impact force is constant $F = m(v2 - v2)/t$

2.10. Performance Analysis :

2.10.1. Runway/Launch/landing Performance :

The diagrammatic representation of takeoff and landing distance on basis of calculations explained below-



Landing Path and Landing Distance

Takeoff Path and Takeoff Distance

Fig. 4 Performance Analysis

2.11. Flight and Maneauver performance :
For manoeuvring performance of airplane, it is an advantage when frequency has the smallest possible R and largest possible W. To obtain small turn radius and large turn rate highest possible factor and lowest velocity is demanded. Considering a home build aircraft.

Minimum turn radius Maximum Turning Angle

$R = \frac{V_\infty^2}{g\sqrt{n^2-1}}$ R= 3.4ft $w = \frac{g\sqrt{n^2-1}}{v\infty\cdot}$ $w = 5.2^0$

2.12. Shading/Downwash : Downwash effect is the vortex lines created during the flight at the wing tips, which decreases the lift of the aircraft by a certain angle, also termed as induced drag. As the wing is long, the distance of wing tips from the body decreases which results in less downwash effect. The downwash angle is given by $\varepsilon = \frac{2Clw}{\Pi ARw} = 0.185$

2.13. Dynamic and Static Stability :

2.13.1. Static Margin Static margin is calculated using the formula given below. Static Margin = (neutral point – centre of gravity)/MAC×100 SM of our plane is 28% of MAC. Horizontal tail and Vertical tail. Position of Horizontal Tail defines longitudinal stability whereas Vertical Tail defines directional stability of the plane. It is given by the formula, Horizontal tail Vht = (Lht+Sht)/(c×S) = 0.4 , Vertical tail Vvt = (Lvt + Svt)/(c×S) = 0.16

2.14. List Of Symbols and Acronyms :

CD = Coefficient of Drag , α = Angle of Attack , $CDmin$ = minimum coefficient of drag , K' = inviscid induced drag , CL = Coefficient of lift , e = Wingspan efficiency , K" = Viscous induced drag , FF = Form Factor,

CF = Skin friction coefficient , SWetted = Weighted surface area ,T = Servo torque (oz -in),

C = Control Surface Chord , V = Speed in mph , L = Control surface length, m = Mass in Kg,

S1 = Maximum surface deflection , S2 = Maximum servo deflection in drag

V2 = Initial Velocity ft/s, V1 = Final Velocity ft/s , Sg = Ground roll, HF = Flux height

V^2t.o. = Velocity in ft/s of take off , μ = Coefficient of Friction , R = Flight path radius in ft.

μr = Rolling friction , V∞ = Velocity at infinity in ft/s, Ɛ = Downwash angle

2.15. Assembly and Subassembly :

Shipping an aircraft as long as 5.347ft can be a challenge economically and in terms of security reasons. This created a necessity to fragment the entire structure. Serviceability dominating this frontier differentiate the structure in four main sections namely Fuselage, Wing assembly, Empennage and Landing gear. Fuselage The main purpose is to house the motor and create effective flow geometry. The carpet area in the nose of the fuselage is crucial in accommodating the ESC and the Battery. With a sturdy flow spanning end to end and representing itself as the longest section, it assures space for 2 large spherical containers (Footballs). Unique design boxed cargo are crucial when it comes to minimize the loading and unloading of the cargo. Wing Assembly : The wing assembly mainly consists of thin and hollow airfoils that are finely sanded by solid integration of balsa and Bassply to supply sturdy and rigid support. Two aileron assembly are attached to each side of wings are governed by two servos each helps pilot to gain manoeuvrability advantages. Empennage : The empennage supports the rudder and elevators. To create sufficient lift forces elevator flap assembly is divided into two sections independent responded by two individual servo. The rudder vertically stands as high as 15.74 inches and is governed by one servo. Integrating of all direction controlling mechanism is done using flat nylon hinges. Landing Gear : During landing, landing gear are the first once to respond hence, they are to be designed carefully. Further considerations show that aircraft tricycle type landing gears are found suitable for the purpose.

III. CONCLUSION

In the conclusion, we believe that this entire process of designing the aircraft helps us grip together theoretical and practical aspects of aircraft design. It helped us explore various specialization fields like Structural Design, Computational Fluid Dynamics, Wood Working, etc. It not only gave students a hands-on experience with hand tools as well as advanced software's, but also gave them an opportunity to interact with industrial tycoons in the field. Designing of aircraft was followed by rigorous quality conformance techniques which again opens new realms for students. Finally, we a group of rookie students learned a process of developing aircrafts from scratch understanding various business and industrial factors.

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