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DESIGN AND FABRICATION OF LOW T/W RATIO AND HIGH PAYLOAD FRACTION MINI UAV

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Abstract— This paper addresses the detailed overview and challenges facing while designing a low thrust to weight ratio and high payload fraction unmanned aerial vehicles from the flight stability perspective. The main focus is to get sufficient pitch stiffness without using any external controllers in the process of achieving high payload fraction. Several Iterations are illustrated with different aerofoils like Eppler, NACA and S1223 to achieve required pitch stiffness. This paper also presents the longitudinal stability analysis and theoretical lateral and directional stability and control derivatives of the Mini UAV.

Keywords— Mini UAV, XFLR5, Pitch Stiffness, Stability derivatives.

I. INTRODUCTION

An aircraft with a high thrust to weight ratio has high acceleration. In most flight conditions, the aircrafts with a high thrust to weight ratio will also have an excess amount of thrust. High excess thrust results in a high rate of climb. If the thrust to weight ratio is greater than one and the drag is small, the aircraft can accelerate straight up like a rocket. But it doesn't mean that an aircraft can't takeoff/fly with a thrust to weight ratio of less than one. Most of the commercial aircrafts have a thrust to weight of less than one. an aircraft with low thrust to weight ratio comes with benefits such as, reduced empty weight of the aircraft, maximum efficiency, reduction in the cost of propulsion system of the aircraft. We are presenting this paper with an aim to design and fabrication of an RC aircraft with low thrust to weight ratio as well as with high payload carrying capability.

II. DESIGN METHODOLOGY

A. Conceptual Design –

Wing loading:

Wing loading is the total weight of an aircraft divided by the area of its wing. The value of wing loading was selected to be in between that of a glider and a trainer.

Wing configuration:

We had three options for choosing the wing configuration that is High wing, mid wing and Low wing. Going for a low wing would be not optimistic since our RC design doesn't have landing gears and choosing a mid wing would lead to manufacturing difficulties and would also consume the space available for the placement of payload, therefore a high wing configuration was chosen, also considering the stability the high wing configuration is Much stable compared to other configurations.

Tail configuration:

Conventional tail configuration was chosen in our design due to its high strength and manufacturing advantages.

Other options such as t-tail, h-tail, v-tail, was not chosen due to their less Strength (t-tail).

Airfoil selection:

Various airfoils such as e234, s1223 were analyzed using xflr , the selection was made based on the best,

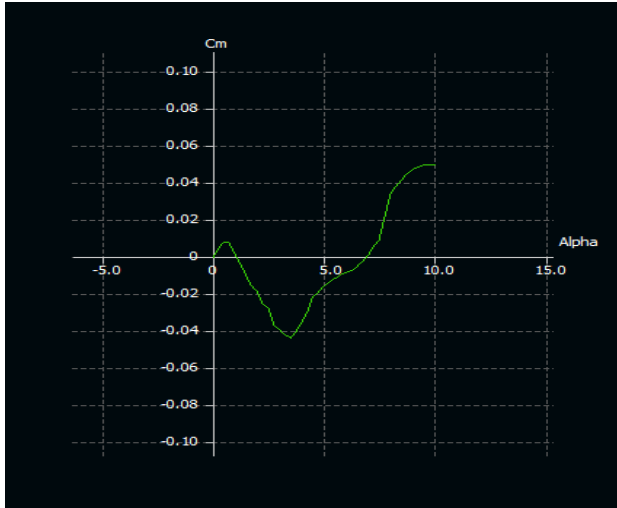
1. Aerodynamic efficiency that is Cl/cd
2. C_l max
3. C_d
4. C_m about aerodynamic chord

The first thing that designing entailed was the selection of an airfoil as it is the primary means to Generating sufficient lift and minimizing drag effects. After an extensive study, Selig S1223 was selected as the airfoil for the aircraft:

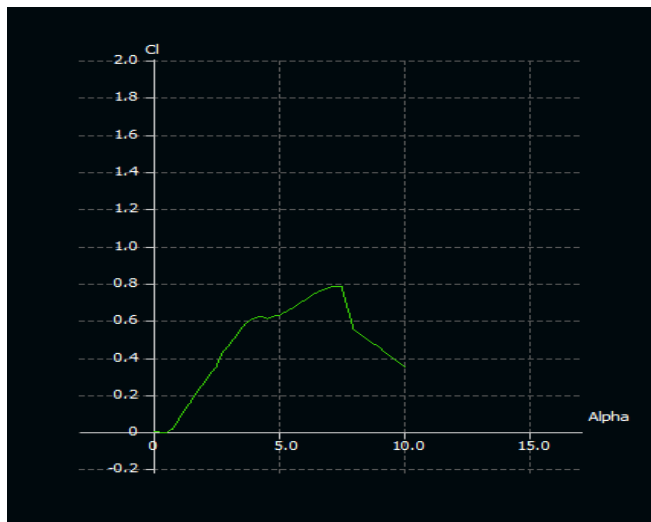
- s1223: for Wing
- naca001234: for tail

XFLR ANALYSIS OF AIRFOIL:

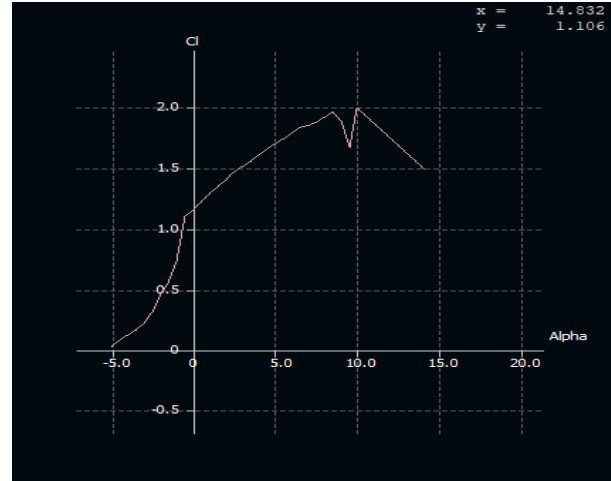
1. NACA001234 (green line)



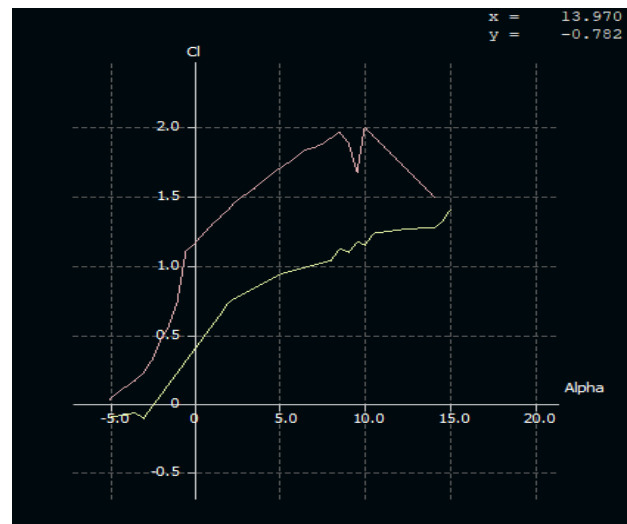
a) Pitching Moment Vs Angle of Attack curve



b) Lift Coefficient Vs AOA



2.a) Lift Coefficient Vs AOA

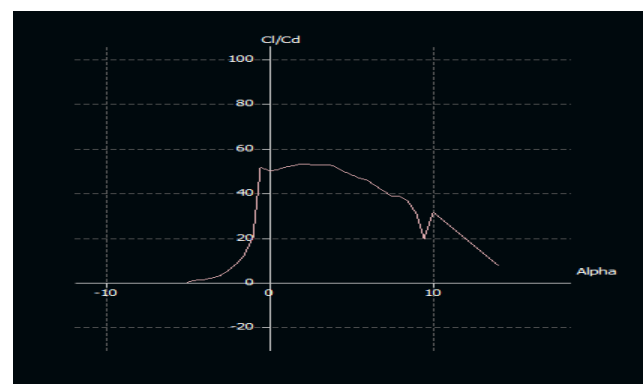


2. b) Comparison Of Lift Coefficient

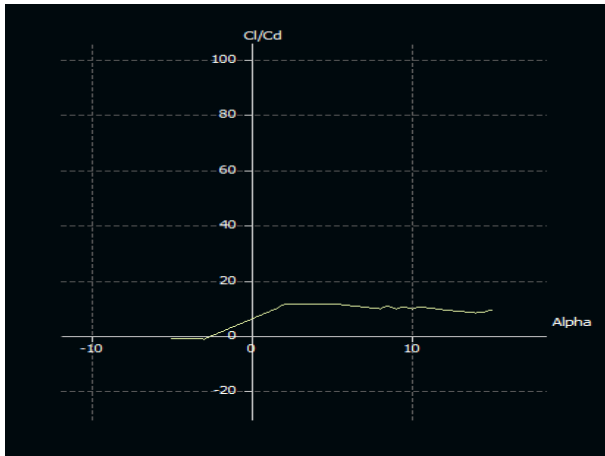
2. S1223(pink line) and E423(yellow line):

Comparison of Eppler and S1223 aerofoils are give below. Fig 2.b represents the comparison of lift coefficient with respect to angle of attack and Fig 2.c gives the aerodynamic efficiency variation along with angle of attack.

From these Preliminary observations it is concluded that S1223 aerofoil is satisfying the required characteristics to design a high payload fraction low thrust to weight ratio unmanned aerial vehicle.



2. c) S1223 aerofoil Aerodynamic Efficiency curve



2. d) E423 aerofoil Aerodynamic Efficiency curve

B. Actual Design

Based on the below shown formulae the aircraft was designed, although the design was finalized after performing stability analysis on xflr5 software.

Standard relations as per stability:

- Wing span (b_w) = $\sqrt{(AR_w * S_{wing})}$
- Wing chord (C_w) = S_{wing} / b_w (for rectangular wing)
- $St = 0.25 * S_w$
- Tail span (bt) = $\sqrt{AR_t * St}$
- $\Lambda = 0.45$
- Tail root Chord $C_{root} = 2St/bt(1 + \lambda t)$
- Tail tip chord $C_{tip} = \lambda t * C_{root}$
- Fuselage length = $4C_w$

The specifications of the model are: -

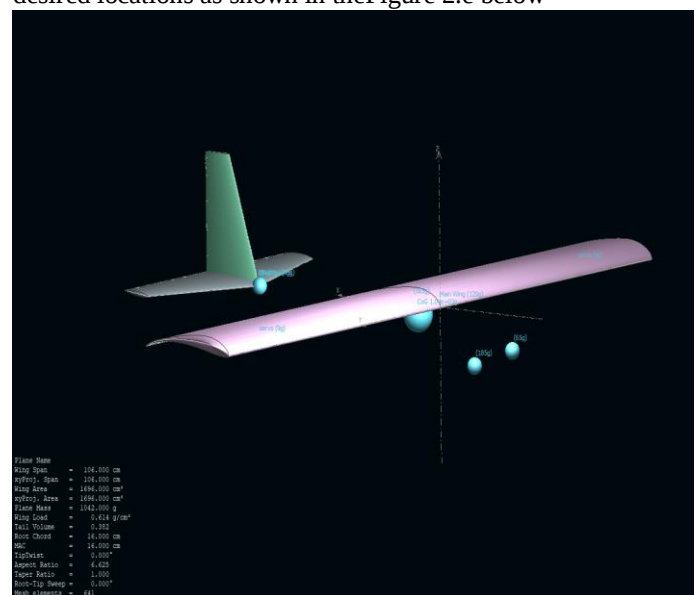
Wing loading without payload(g/cm ³)	0.381
Chord	16 cm
Wing area	1696 cm ²
Aspect Ratio	6.625
Tail area	307cm ²
Tail span	41.2 cm
Root chord	10.3cm
Tip chord	4.6cm
Rudder height	16.48 cm
Fuselage length	64 cm

Electronics used:

Motor	Racer star BR2826 1290KV 2-4S
Servo	sg90
Transmitter/receiver	Fly Sky FS-i6 2.4G 6CH PPM RC transmitter with FS-iA6B receiver
Esc	30A

- Glide test was carried out on the model to check the lift as well as to rectify any possible Correction to be made in the model; based on which Control surfaces have been properly trimmed as per requirement to ensure roll and yaw stability.
- The no of channels required were five so, a Fly Sky FS-i6 2.4G 6CH PPM RC transmitter withFS-iA6B receiver is being used to control the aircraft.
- Motor was roughly chosen based on the gross thrust to weight ratio, later thrust was reduced to the minimum value, from the motor the net current required by the aircraft was determined, based on which a 30 amp electronic speed controller Chosen. Sg90 servos were used to operate the control surfaces during the entire flight. The motor is coupled with a 1045 propeller to get the required thrust output.
- Neutral point is at 121 mm and the pitch stiffness is - 1.2999 /radian

Stability analysis was executed with the payload placed at the desired locations as shown in theFigure 2.e below



2.(e) Stability analysis of UAV in XFLR5

III. FABRICATION

To go forward with the fabrication, the SOLIDWORKS model is made where all the weight Constraints are estimated. Particularly balsa Wood is used for maximum payload fraction. Then each Part dxf software 2D diagram is taken for the laser cutting, later attached each components with glues.

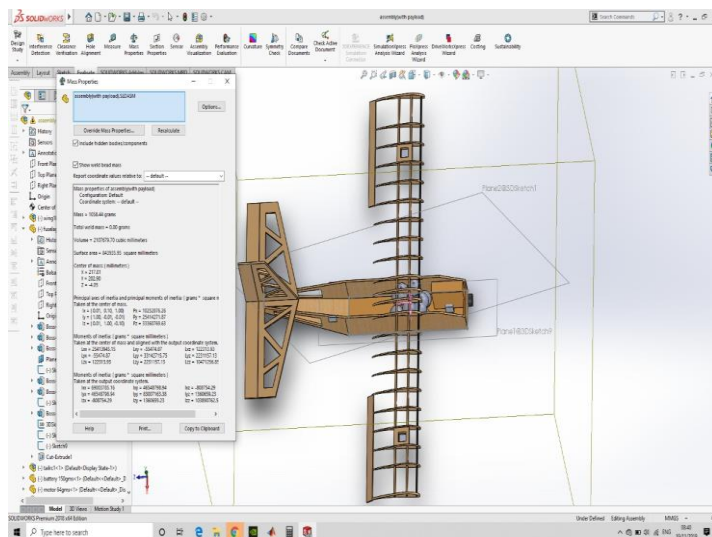
A) Solid works model

A preliminary solid works model was designed as shown in fig 3.(a) to get a rough weight approximation, and also further design tweaks which had to be done to optimize the space inside the fuselage were made.

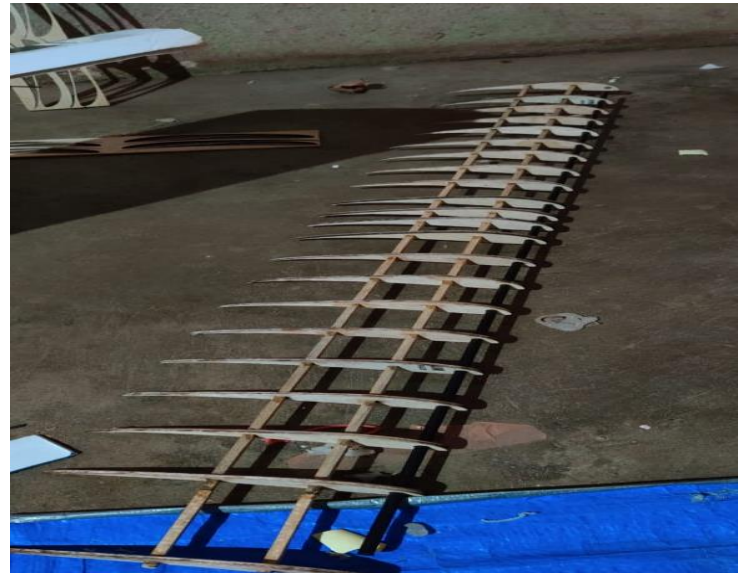
B) Fabrication

WING

- For wing construction, only ribs with desired airfoil shape are cut. Rectangular and circular holes are Made in the ribs for spars.
- There are 3 spars used. To make the wing stiffer and to make it Capable of lifting the loads of the aircraft, one of the spars used is a carbon fiber rod.
- Carbon fiber Rod was chosen due to its high strength to weight ratio.
- Rib spacing was determined based on span of the wing, mid wing portion was especially made with thick airfoils (6mm) to make the structure more rigid. after the placing the ribs and spa rat required positions the wing was covered with monokote(red) which was glued to the ribs using a iron box.



3. (a) SOLID WORKS model



3.(b) Wing Fabrication

CONTROL SURFACES

The control surfaces were designed using the standard relations as per stability, and were cut from balsa wood. Servo motors were utilized for the actuation of these control surfaces. For coupling servo motor and control surfaces pushrods, control linkage and control horns have been used.



3. (c) Final Model



IV. RESULT

After Successful flight testing the following results were obtained,

Table -1 Experiment Result

T/W	EMPTY WEIGHT	PAYLOAD	PAYLOAD FRACTION
0.4	742g	630g	0.849

Table 1 addresses the total payload fraction is 0.849 with thrust to weight ratio is 0.4.

V. CONCLUSION

Design and fabrication of the RC aircraft has been successfully carried out, with the desired stability criteria and minimum thrust to weight ratio of 0.4 has been achieved.

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