DESIGN AND FABRICATION OF A MEDIUM SIZE UAV WITH SMART LOCK-SYSTEM FOR WINGS

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ABSTRACT

This paper summarizes the entry of undergraduate students' team for a competition. The team was formed to design, build, test, and fly an Unmanned Aerial Vehicle while keeping in mind to ease the manufacturing and assembly processes capable of lifting heavy loads. The configuration of the aircraft was chosen based on low power to weight ratio and design constraints. To ensure the required aerodynamic forces are met and to distribute the landing impact loads better through the airframe, the CATIA V5, Airfoil section, and structural integrity of landing gear was analyzed using ANSYS 16.2 software. To reduce the unnecessary weight, the structure of the wing and fuselage section was examined. A smart locking system was designed and integrated with the structure to ease the assembly process and to ensure safe attachment of the wing to the fuselage.

KEYWORDS: Smart Locking System, Heavy Loads, Airfoil & Landing Gear

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1. INTRODUCTION

An Unmanned Ariel Vehicle (UAV), commonly known as a drone is an aircraft without a human pilot aboard. These aircraft are broadly classified into three categories, namely: Fixed-wing, Rotary wing, and flapping wing UAVs. They are also classified based on size, range, and endurance. Under the fixed-wing category, we have Micro, Mini, Medium, and Large UAVs; Close-range UAVs, Short-range UAVs, Mid-range UAVs and Endurance UAVs; MALE and HALE [1]. UAVs have wide-ranged applications in the industrial, public, and military sectors. Mapping and surveying, inspection and monitoring, aerial imaging, precision agriculture are some of the most important applications.

Traditionally wings are attached to the fuselage in the following three ways:

- Spliced Shear Plates
- Tension Bolts
- Lug Fittings

Though these methods have proved to be sturdy and efficient, we have devised a smart lock system capable of not only safely securing the wing to the fuselage but also enabling speedy assembly and dismantling along with easing the manufacturing process.

The goal of this team was to design twin-boom tail aircraft that will remain light and still be able to lift a heavy payload. Boom tails are used when an aircraft's fuselage does not extend entirely back to the horizontal stabilizer. It is characterized by two longitudinal booms fixed to its main wing on either side of its centerline. The types of boom tail include, but are not limited to boom-tail, high boom-tail, and inverted v-boom tail.

The advantages of a boom tail are:

- They provide the opportunity to include a very large, robust elevator relative to a single-tailed aircraft, which provides very good control at normal speed.
- They can also stiffen/brace the wing structure in general, and distribute the load more gently.
- The design of twin-boom in an aircraft allows the fuselage to be made very compact and so lighter.

2. LITERATURE STUDY

2.1. Product Study

Table 1: Product literature study

Model	Length	Wing Span	Mtow	Payload	Cruise Speed	Range	Endu-Rance	Payload Ratio
DVF 2000	1.2m	3m	10kg	1.1Kg	61.2-97.2 km/hr	5km	-	0.11
Eagle eye	3.02m	4m	35kg	-	50km/hr	-	2hrs	0.57
Mini Mugin	2.05m	2.6m	15kg	4kg	120km/hr	-	2hrs	0.26
Mugin Plus	2.53m	4.5m	28kg	8kg	45-120km/hr	10km	2hrs	0.28
MFD Nimbus	1.3m	1.8m	5.5kg	1.5Kg	140km/hr	-	-	0.27
Eagle Hero	1.61m	3.5m	16kg	7.5kg	86km/hr	-	6.5hrs	0.46
Albatross	0.74m	3m	10kg	4.4kg	60-72km/hr	-	4hrs	0.44
Sky Hunter	1.4m	1.8m	3.5kg	-	-	5km	2hr	-
Penguin B	2.27m	3.3m	21.5kg	10kg	79.2km/hr	-	20hrs	0.46
RQ-2 Pioneer	1.4m	3.5m	10kg	-	72km/hr	5km	-	-

Weight estimation of UAVs requires collecting data from existing UAVs, which are similar in characteristics, mission plan, and takeoff weight and payload capacity. A comprehensive study of 10 existing products was carried out, a few of which are mentioned below. (2-7)

2.2. Graphical Representation of Product Data

Taking into consideration the data required for weight estimation and design calculation, graphs were plotted between the important parameters of the existing products. After analyzing the obtained graphs, the desired values were estimated from the most clustered area of the graph.

Figure 1: Graphical Representation of Product Data.

3. METHODOLOGY

This section describes the methodology adapted to the development of the UAV. The philosophy of this team throughout the design process has centered on developing sound fundamental concepts to satisfy competition requirements. After a satisfactory output, the final model is fabricated and tested. Required changes are made and the model is finalized.

3.1. Flowchart

4. UAV DESIGN CALCULATION AND CAD MODELING

4.1. Airfoil Selection

Airfoil plays a crucial aerodynamic role in generating lift. The airfoil determines the performance characteristics of the designed UAV. The selection of an airfoil for the wings is the primary means to ensure sufficient aerodynamic forces. For

an aircraft such as this one, the wings must provide high lift at an approximate Reynolds number of 150,000. This Reynolds number was calculated using an assumed aircraft velocity of 45 km/h, a chord length of .4 m, and historical environmental conditions. The team investigated a few airfoils and found two very promising those are NACA 63-412 and AG35.

The important characteristics of the airfoil are thickness to chord ratio, location of the aerodynamic center, leading-edge radius, etc.

The following graphs:

- CL v/s Alpha
- CD v/s Alpha
- CM v/s Alpha
- L/D v/s Alpha

were generated for the selected airfoils and the results were analyzed to finalize the required airfoil.

Figure 2

Figure 3: The Graph between the Different Parameter of NACA 63-412 and AG 13.

4.2. Weight Estimation

The weight of the aircraft is a key factor in most aircraft performance problems. Lowest weight of aircraft design is a subject of utmost importance, although weight minimization is attained at some additional initial cost, it proves beneficial in the long run.

The maximum takeoff weight for an aircraft is the total designed weight when it begins its mission. For any UAV,

$$W_0 = W_e + W_{pl} + W_f$$

Where is the W_e empty weight, W_{pl} is the payload weight, W_f is the fuel weight.

Figure 4: Take-off Weight Estimation.

Table 2: Takeoff Weight Estimation

S No	Particulars	Weight
1	Battery	0.7kg
2	Payload	1kg
3	Structure	2.4kg
4	Electronics	0.45kg

Structure weight is the combined weight of wing, fuselage, and empennage of the UAV. And usually accounts for about 32% of gross weight.

Table 3: Structure Weight Estimation

S. No	Particulars	Weight
1	Left-Wing	645g
2	Right Wing	645g
3	Fuselage + Payload cabin	455g
4	Vertical tail	265g
5	Horizontal tail	190g
6	Boom	200g

Figure 5: Structure of Weight Estimation.

Electronic components play a major role in the working of a UAV. The combined weight of all the electronic components contributes to the electronic weight.

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Table 4: Electronics Weight Estimation

S. No	Particulars	Weight
1	Electronic Speed Controller	90g
2	Ducted fan +Motor	300g
3	Servo	
4	Wires	10g
5	Receiver	50g

Figure 6: Electronics Weight Estimation.

4.4. Design Calculation and Formula used

Table 5: Design Calculation Formula and Dimension

S.No	Parts	Name(Formula)	Dimension
1	WING	Wing loading (W/s)	7.386kg/m ²
		Wing surface area	0.676m ²
		Aspect ratio	7.68
		Taper ratio	0.6

		Wingspan ($\sqrt{(AR \times S)}$)	2.27m
		Chord rootlength ($2S / (b \times (1+\lambda))$)	0.40m
		Chord tiplength ($\lambda = Ct/Cr$)	0.24m
2	HORIZONTALTAIL	Surface area (30 % of wingspan)	0.2028m ²
		Aspect ratio	3
		Span ($\sqrt{(AR \times S)}$)	0.8m
		Taper ratio	0.6
		Chord rootlength ($2S / (b \times (1+\lambda))$)	0.31m
		Chord tiplength ($\lambda = Ct/Cr$)	0.18m
3	VERTICAL TAIL	Surface area(70% of the horizontal tail surface)	0.08112m ²
		Aspect ratio	2
		Span($\sqrt{(AR \times S)}$)	0.40m
		Taper ratio	0.6
		Chord rootlength ($2S / (b \times (1+\lambda))$)	0.27m
		Chord tiplength ($\lambda = Ct/Cr$)	0.16m
4	ELEVATOR	Length (20 % of horizontal tail)	0.040m
5	RUDDER	Length (1/8 of a chord)	0.03125m
6	FUSELAGE	Length (70% of wingspan)	1.589m

4.5. 2D Draft View

Figure 7: 2D Draft View.

4.6. CAD Model

Figure 8: (a) Assembled View (b) Bombarded View
(c) Various View of Aircraft.

5. SELECTION OF PROPULSION SYSTEM

- Weight = 5kg
- As per the list $T/W = 0.5-0.7$
- Required thrust $T/5=0.5$
- $T=2.5$ (minimum thrust)

Table 6: Electronics Components Details

S. No	Components	Specification
1	Motor: Motor: DUCTED FMS 80mm 12 Blades Ducted Fan EDF with 3270 KV2000 6S in runner Brushless Motor	<ul style="list-style-type: none"> • Item Name: 80mm 12 blades Ducted Fan • Motor: 3270 KV2000 • Weight: 300g • Battery: 6S 4000mAh 45C lipo • ESC: 100A brushless • Maximum thrust -3200 g
2	ESC: Fly color V1.3-win dragon WIFI 100A 2-6S Lipo Brushless ESC for RC Airplane Aircraft	<ul style="list-style-type: none"> • Continuous current: 100A • Instantaneous current (10s): 120A • BEC: 8.4V/7.4V/6V/5V, 3A • Support voltage: 2-6S • Weight: 125g • Size: 82.5x39.5x23.5mm
3	Battery: ORANGE 16000mah 6S 25C/50C lithium polymer battery pack (lipo) Orange	<ul style="list-style-type: none"> • Model No: ORANGE 16000 / 6S-25/50C • Capacity: 16000 MAh. • Weight: 1900 gm. • Voltage: 22.2 V.

4	Servo: Power HD AR-1201MG Servo 12 to 13 KG Torque	<ul style="list-style-type: none"> • This is a powerful metal gear servo with torque ranging between 12 to 13KG. • This servo runs on 4.8V and 6V and strictly not more than 6V. • Weight is 60g • This servo gives a full 180-degree rotation.
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Calculation

- ESC Rating $\text{ESC rating} = [1.2 \text{ to } 1.5] * (\text{max. ampere rating of the motor})$
- RPM $\text{Rpm} = \text{KV rating} \times \text{Battery Volt input}$
- Flight Time Capacity in amperes/ $(\text{Current draw}) * 60$

6. ANALYSIS

6.1. Airfoil Analysis

The performance of the airfoils was analyzed using XFLR

Figure 9: Performance Analysis of Airfoil using XFLR.

The figure depicts the following graphs

- Cl vs. Cd
- Cl vs. Alpha
- Cl vs. Xtr top
- Cm vs. Alpha
- Cl/Cd vs. Alpha

6.2. Structural Analysis

Structural analysis was done for optimizing landing gear design.

Figure 10: (a),(b) Structural Analysis for Optimizing Landing Gear Design.

7. FABRICATION

7.1. Smart Locking System for Wings

For the smart locking system, we have chosen an umbrella's locking mechanism that will hold and lock both the wings with fuselage acting as a secure lock instead of a screw lock or rubber band locking system (usually employed in gliders and small UAVs). In this system, we have used two umbrella locking system: both the locks connected to each wing. As seen in the figure below, the main airfoil-shaped block is fixed in the fuselage. Inside these blocks, holes are drilled and the locking system is placed. The rod-like structure similar to an umbrella runs through the length of the wing, and it snugly fits in the main block where it's latched with the help of the locking system. This system makes it easy to manufacture and also to assemble the model.

Figure 11: (a) Wing Locking Mechanism, (b) Wing Fabrication.

Figure 12: A Finalized Model of UAV

CONCLUSIONS

The conceptualized design and analysis of a smart lock system based on regular class Remote Controlled Aircraft is done and the various design considerations and performance parameters required are calculated and found out. The obtained design values are not necessarily a definite reflection of the airplane's true and conceptualized design as little variations are expected while manufacturing, but the basic outlay of development has been obtained. Assumptions in some calculations were made after considering all the related aspects and references required for that. There is no ideal design as such as continuous changes, improvements and innovations serve to make the design as ideal as possible, while always looking to achieve optimum performance and payload carrying capacity. The challenges we faced at various phases of the project made us realize that the experience plays a vital role in the successful design of any aircraft or aircraft component. A lot of effort has been put into this product and as much as we have worked, we have learned in turn.

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