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DESIGN OF A CANARD-WING UAV

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Abstract- In this project, we intend to design a Canard wing-based Unmanned Aerial Vehicle (UAV), which can carry a wide range of missions, providing capabilities to handle out challenges with sophisticated care. Canard-based UAV is the latest trend in aviation technology designed for the use case of providing better manoeuvrability, which in result gives the UAV new capabilities, such as increased time for data gathering, transferring, and autonomous behaviour.

The basic disciplines like Aerodynamics, Engineering design, Flight dynamics, Propulsion, and Performance are carried out during the UAV designing process. The proposed methodology applied in this project is weight estimation, initial sizing, aerofoil and wing geometry, fuselage sizing, tail sizing, T/W ratio, aerodynamics, and performance analysis. The design of Canard Based UAV leads to a deeper understanding of the trade-off studies of the UAV and is demonstrated by optimizing for designed missions like surveillance. A drafted sketch is presented at the end of the design phase featuring the selected configurations of major components.

Keywords – Canard – wing, Airfoil, Tapered wing, Hawk-i1

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1. INTRODUCTION

UAVs are the class of aircraft that fly without the presence of on-board pilots. It is the most emerging technology advancement in the world. The path to acceptance of UAVs and recognition of their worth has been protracted and strewn with obstacles. They have new capabilities, such as increased data gathering, transferring and autonomous behaviour. These are successfully used in surveillance, delivery, search & rescue, etc.

We have opted to enhance the performance of a canard aircraft by combining the vital roles of canard concepts without compromising on payload fraction, structural weight and design a UAV that is capable of carrying a payload of 7kgs and perform surveillance activities. Our motive is to develop a remote-controlled aircraft to take off, manoeuvre, and land while carrying as much payload as possible. All along we have further pushed our limits and implemented some innovative ideas in the model that are mentioned below.

2. EXECUTIVE SUMMARY

2.1 PROJECT SCOPE

The objective of the team is to fabricate a Multi-disciplinary UAV with the concept of canard wing configuration. The testing and analysis of fabricated models should give a brief idea of the effects of CANARD AIRCRAFT on overall performance, providing the practicality of the payload design.

3. DESIGN PROCESS

The process of designing our aircraft is displayed using the flow chart provided below. Beginning from the conceptual design, considering all the constraints and requirements, we have gone through each phase carefully & accurately.

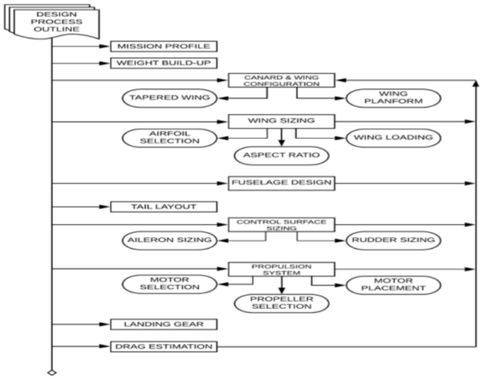

FIGURE 1: DESIGN PROCESS

4. MISSION PROFILE

A mission profile is the detailed description of the aircraft’s flight path and its in-flight activities. Hawk-i1 carries out a different flight path for each of its applications, as shown in the figure.

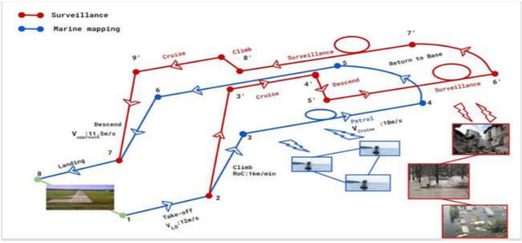

FIGURE 2: MISSION PROFILE

A simple mission profile with take-off, climb, cruise/patrol, descent, landing segment, as shown above, were taken as the primary target for the UAV to complete its mission profile.

5. WEIGHT BUILD-UP

Gross weight is the total weight of the designed aircraft as it begins the mission for which it was designed. Weight buildup is the important phase of calculations where several parameters like lift, drag, thrust, stall speed, and many more are considered. The empty weight of the aircraft includes the structure, engines, landing gear, avionics, fixed equipment, and anything else which is not considered as a part of the crew, payload, etc.

S.No	Component	Quantity	Weight (grams.)
1.	Structure	1	1895
2.	Motor	1	550
3.	ESC	1	155
4.	Servos	5	400
5.	Battery	1	700
6.	Propeller	1	100
7.	Landing Gear	1	1200
8.	Payload	1	7000
	TOTAL		**12000**

TABLE 1: WEIGHT BUILDUP

The above table shows the preliminary weight build-up of the complete model, i.e. the weight of the model including payload. This approximated to an exact value of 12000 grams.

6. CONFIGURATION SELECTION

Configuration of aircraft is one of the key parameters to determine the overall performance of the aircraft. The aircraft configuration gets selected based upon the aircraft type and its purpose to ensure the aircraft gets succeeded in its activities need to be done. To fulfill the design requirements and constraints, numerous aircraft configurations are possible based on the following variable:

- Canard wing configuration
- Tapered wing

6.1 CANARD WING

The key motive behind selecting a canard wing is to enhance the vital advantages. The addition of a canard wing in the UAV design helps the UAV to operate for multiple purposes. The primary benefit of the canard is it can be made to stall first than the main wing and works as a stall indicator resulting in a stall–proof indicator. The aerodynamic advantage of the canard tail is producing positive lift rather than negative lift that helps in generating more lift, most importantly during takeoff and landing. The structural benefit of the canard wing is sharing the wing loading countered by the requirement of more wing surface area, increase in structural weight, indeed helps in fulfilling the dimension constraint (L+B+H <= 170) comfortably.

Generally, the canard is known to provide more maneuverability and inadequate stability for the UAV (mostly lifting canard aircraft). To have adequate stability and capability of maneuvering (if required) for the UAV, the team had analyzed and decided to adopt the advantages of both control canard and lifting canard i.e., mix up of both canard configurations.

6.2 TAPERED WING

The main motto behind selecting a tapered wing with a zero-degree leading-edge sweep is to decrease the drag without compromising on the lift and maintain the C.G in the stable static margin to ensure the stability of the UAV. The taper wing helps in minimizing the induced drag. Elliptical wings are the most efficient but hardest to build. We can have elliptical lift distributions with a taper ratio of 0.44, but an increase in taper will make the wing thicker at the root, will be stronger and lighter but, it might lead to stall & which increases the induced drag as the span of the wing needs to be more to achieve the required lift. Hence, a moderate taper is selected.

7. WING SIZING

7.1 AIRFOIL SELECTION

The airfoil selection for an aircraft's wing plays a prime role in overall UAV aerodynamic performance and its design process. Many performance parameters such as L/D ratio, stall speed, take-off, landing performances, and many other parameters depend on the characteristics of the airfoil parameters. After performing rigorous research and analysis on airfoils available in the airfoil database, S1223 airfoil (for the main wing) has been selected and modified the trailing edge using inbuilt modification tools, namely spline tool (XFLR5 Software), to increase its manufacturing feasibility. Due to the modification, the graph of aerodynamic performance parameters is slightly fallen by a bit, but they fulfill our desired requirements. Hence, we decided to go with a modified S1223 airfoil.

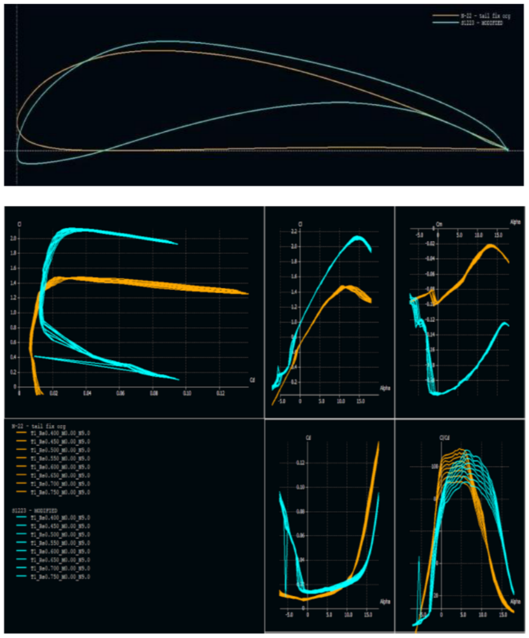

FIGURE 3: MODIFIED S1223 & CANARD AIRFOIL CHARACTERISTICS

7.2 ASPECT RATIO

For a canard wing aircraft, the aspect ratio of wing & canard plays a vital role in stability and control. To make sure the canard wing act as a stall proofing indicator, the stall AOA of the canard wing to be lower than that of the wing, to achieve that the AR of the canard to be high w.r.t the main wing. The larger AR reduces the stall AOA while smaller AR does the vice-versa.

Another benefit of having higher AR for a small canard wing is it provides a steeper lift curve slope that produces higher lift at a given AOA, but a much higher AR for a short chord with a low Re might lead to creating undesirable characteristics at low speeds such as the formation of a span-wise vortex that might lead to detrimental stall characteristics. Hence, AR plays a great vital role in canard UAV. To maintain the stability and utilize the advantage of having high AR for canard, the aspect ratio of the canard is selected to be 6 where the aspect ratio of the wing is selected as 5.

7.3 WING LOADING

Wing loading is a critical parameter in the design phase & parameters such as take-off & landing distances varies concerning wing loading. It is also used for the measurement of the Vstall of the aircraft. Aircraft with a larger wingspan have less wing loading, this helps in improving the performance of aircraft but leads to additional drag & an increase in empty weight. Hence, the addition of a canard wing to the design helps in sharing the wing loading that provides us a lead to go with a shorter wingspan rather than a larger one to achieve the required performance. As per the calculations, wing loading of 3.34 lb./ft2 is obtained that matched the historical data trend of RC a/c.

FIGURE 4: WING LOADING vs. STALL VELOCITY GRAPH

8. EMPENNAGE CONFIGURATION

The Tail of the aircraft is called the “Empennage,” which is mainly responsible for the Control and Stability of the UAV, in particular longitudinal and directional. The two stabilizers (Horizontal and Vertical) are used to trim the aircraft, Controlling the Pitch and yaw movements, respectively. There are many innovations and improvements in the empennage design in past years, and they are classified based on attachments, Shapes (H-tail, V-tail, T-tail), etc. Every design has a unique advantage over the other depending on the requirement of the mission, the configurations are analyzed, and the fore-plane/ Canard Configuration are selected, which best suits the purpose.

8.1 HORIZONTAL STABILIZER

Generally, the Horizontal Stabilizer is used to control the longitudinal stability of the aircraft (i.e., Pitch control). The configuration for the Horizontal tail is selected to be “Canard Configuration.”

Canard is selected since it can contribute to the lift and acts as a small wing, and typically it will generate 25% of the overall lift, and the main wing contributes to the rest 75%. This configuration has the advantage of higher payload carrying capacity than the conventional. The Canard configuration will have higher efficiency since it will be in front of the wake region of the wing. The area of the horizontal stabilizer is directly proportional to the lift, stability, and drag. Hence the canard sizing is done much precisely to minimize the drag as much as possible. The estimated surface area of the horizontal stabilizer is about 22% of the wing area.

Generally, based upon the historical trends, the tail volume ratio of a control canard is 0.01, and there is no particular tail volume ratio for a lifting canard. As our design is a combination of both the canard type configurations to minimize the downwash effects & utilize the downwash to improve the performance, the distance between the aerodynamic centers of the canard to the aerodynamic center of the main wing is finalized to be 51.82cm.

8.2 VERTICAL STABILIZER

The vertical stabilizer is fixed at the aft of the fuselage in the vertical direction used to make the aircraft directionally stable. For high subsonic aircraft, the thickness ratio of the vertical tail should be 2% lower than the wing thickness ratio. The aspect ratio of the vertical tail should be 2 to 3 to maintain directional stability. The taper should be 0.3 to 0.8 for lower induced drag. The vertical tail ratio should be 0.04 to 0.09. Hence, generally for homebuilt & general aviation single-engine aircraft, 0.04 is preferred based on the historical data.

9. CONTROL SURFACE SIZING

9.1 AILERON SIZING

The aileron is the primary control surface that produces the (Lateral stability & control) rolling moment for the aircraft & makes the aircraft to be laterally stable. The amount of rolling moment depends on the function of aileron size, aileron deflection, & its distance from the centerline of the fuselage. The chord of aileron sizing should be 25% of the wing aerodynamic chord & the span should be 50% of the wingspan.

9.2 ELEVATOR SIZING

The elevator is the primary control surface located on the horizontal stabilizer that produces pitching moments & will make the aircraft longitudinally stable. To generate sufficient pitching moment and to have stability, the complete area of the canard will be operating as an elevator.

9.3 RUDDER SIZING

The rudder is the control surface located on a vertical stabilizer that produces yawing moment and makes the aircraft directionally stable. The positive moment will tend to turn the UAV in the right direction, and the negative moment will tend to turn the UAV in the left direction. The rudder chord sizing should be 25% to 50% of the vertical stabilizer chord & the span of the rudder should be 50% to 90% of the span of the vertical stabilizer.

Control Surface	**Chord (m)**	**Span (m)**	**Area (m^2)**
Ailerons	0.0875	0.4375	0.038
Elevator	0.15	0.9	0.135
Rudder	0.09	0.405	0.036

TABLE 2: CONTROL SURFACES SIZING

10. POWER PLANT MATCHING

A Pusher configuration is selected to avoid the irregular flow of wind over the canard, to have better stability. Thrust or power required is a function of drag. Thrust required is equal to drag whereas, the power required is drag times velocity (P=V*D). As thrust is directly proportional to drag, the minimum thrust required for the aircraft is taken from the drag forces that the UAV produces. Evaluating the drag force created by the model gives us the minimum thrust required for the aircraft.

By considering the constraints, the following power plant is shortlisted and to have minimum drag.

Motor-Dual sky XM6352EA-V3	
KV	380 KV
Weight	511 g
Dimensions	63.1 mm X 55 mm
Power	2455.9 W

Max. current drawn	120 A
Battery- Dual sky XP52006ECO	
Capacity	5200 mAh
Voltage	22.2 V
Weight	690 g
Dimensions(mm)	158 X 43 X48
Max cont. Discharge	25 C

TABLE 3: POWER PLANT SELECTION

10.1 STATIC & DYNAMIC THRUST

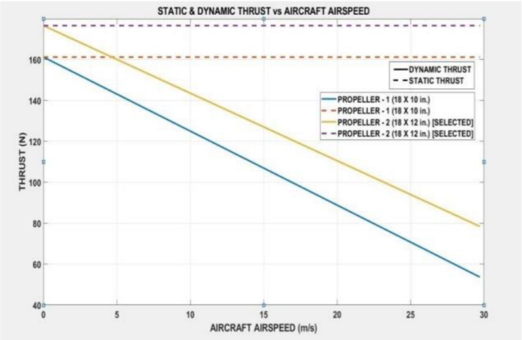

FIGURE 5: STATIC & DYNAMIC THRUST vs. AIRCRAFT SPEED

11. LANDING GEAR

The landing gear is the undercarriage to the primary structure of the aircraft. It provides the critical structural load of the aircraft during taxiing, take-off, landing, and other round operations. There are various types of landing gear configurations and their mechanisms. After continuous research & numerous analysis performed by the team, since the propulsion unit of the UAV is pusher type, the TRICYCLE-type landing gear is opted for because of its advantages. A few of its pros are as follows:

1. A tricycle landing gear has less drag in the initial stage of take-off.
2. Greater propeller clearance for the pusher-type propulsion system.
3. Easier to land

Landing gears are designed to withstand an impact load of 28.66lbs. Based on preliminary studies on tri-cycle those are near to our conceptual sketch. The thickness of wheels should be 0.98 in., wheel diameter of 3.14 in., the diameter of the nose wheel is 2.36in. And the thickness is 0.98in.

12. DRAG ANALYSIS

The drag is one of the most important parameters for an aircraft. It opposes and limits the forward movement of the aircraft. To estimate the required thrust for our UAV the drag should be calculated. It needs to be calculated on all the parts & components of aircraft to determine the overall drag of the aircraft. Generally, drag is generated over the body of the aircraft due to shear stresses, trailing vortices at wingtips due to lifting which is called drag due to lift (or) induced drags and due to integrated static pressures which are normal to the surface area of the wing. Based upon the historical trade studies, the percentage of drag generated by various parts during take-off is displayed using the pictorial graph below.

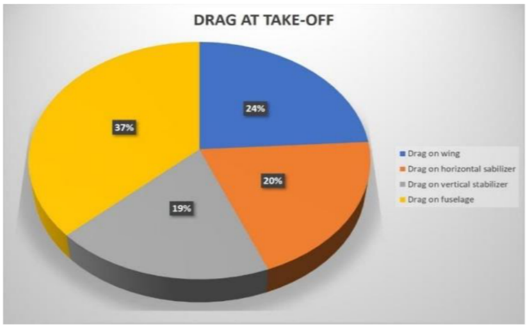

FIGURE 6: DRAG CREATED BY VARIOUS PARTS OF UAV DURING TAKE – OFF

13. PERFORMANCE & STABILITY

13.1 SERVO SIZING

The main motive behind servos sizing is to determine the servo-motor torque required to overcome the moment produced by control surface deflection. It is also applicable to calculate the motion system's optimal inertia ratio. Inertia ratio is the ratio between load's inertia to the motor. Servo drives can be controlled via several interfaces. The positioning of servos is also critical. Futaba S3003 is chosen for our a/c.

13.2 TAKEOFF PERFORMANCE

The ground roll distance of the UAV is 39.74ft., the coefficient of ground friction is about 0.04 from historical data & the ground velocity is 42.65 ft./s. The airborne distance we calculated for our UAV is 101.003ft. & the obstacle height is considered as 15ft. The sum of ground roll distance and airborne distance is called take-off distance. We got a total take-off distance of 140.743ft.

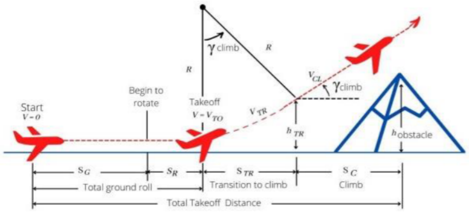

FIGURE 7: TAKE-OFF PERFORMANCE

13.3 LANDING PERFORMANCE

At that time the plane is following a straight path approaching with an angle of 3°. At a distance of Hf=0.517ft from the ground, the UAV flares as a transition to the horizontal ground roll. The distance measured on the ground from the obstacle to the flare is Sa = 255.35ft. The distance covered during the flare on the ground is Sf = 19.77 ft. The distance up to the point where velocity v is 0 is the ground roll Sg= 124.69 ft. The priority for the shorter landing is equally significant to that of a shorter take-off.

14. ESTIMATION OF CENTRE OF GRAVITY

The Centre of Gravity (C.G) of plane should be at the aircraft Aerodynamic Centre for longitudinal stability. The C.G of this aircraft from fuselage nose (considering origin) is estimated as (21.02, 0, and 0.17) inches with and without payload. The aerodynamic center of the wing is 24.63 inches from the datum. C.G estimation is done using CATIA V5 software. A static margin of 6% is assumed to maintain the stability of our UAV. The Weight and position of C.G of a few of the components of aircraft are mentioned below.

COMPONENT	**WEIGHT (lbs.)**	**POSITION OF C.G (in.)**
Motor	1.12	(55.11,0,0)
Battery	1.54	(0.39,0,-2.85)
Payload	15.43	(21.02,0,-1.43)
ESC	0.34	(0.19,0,2.85)
Camera	1.13	(0.39,0,-2.83)
Wing Servo	0.35	(26.19,0,3.78)
Canard Servo	0.35	(5.19,0,0.30)
Vertical Tail Servo	0.17	(48.22,0,11.05)

TABLE 4: ESTIMATION OF CENTRE OF GRAVITY

15. MODELING & ANALYSIS

15.1 MAIN ASSEMBLY

In Modeling, the aircraft body is designed individually i.e wing, tail, fuselage, etc. All the members or individual components are assembled. At last, the aircraft's skeleton body is mono coated with covering film to gain proper finishing and minimize the drag. The final preparations are done to test the flight. All the servos will be tested, and their working or functioning during flight testing. Final check will be conducted to ensure a safe and successful flight.

FIGURE 8: MAIN ASSEMBLY

16. CONCLUSION

Successfully designed a Canard wing aircraft with a fusion of both types of canard & analyzed as per the given specified constraints. This UAV can multi-task activities such as transportation of goods, performing surveillance activities & safety operations such as marine time surveillance, forest fire monitoring & many more.

Parameter	Requirements	Achieved
Dimensional limit	170in.	157.4in.
Empty Weight	5Kgs	5Kgs
Take-off Weight	-	12Kgs
Power plant	Electric	Dual sky XM6352EA-V3
Landing ground run	400 ft.	124.69ft.
Take-off Distance	200 ft.	39.74ft.
Materials	No FRP or Lead	BALSA, PLY & Al
Battery	6 cell Li-Po 22.2 Volt	6S 22.2V Li-Po Battery
Propellers	-	18 x 12 in.

TABLE 5: CONCLUSION

17. REFERENCES

1. Jaffar Syed Mohamed Ali1, M. Mubin Saleh, “Experimental and Numerical Study on the Aerodynamics and Stability Characteristics of a Canard Aircraft”, Journal of Advanced Research in Fluid Mechanics and Thermal, ISSN: 2289-7879, Sciences53, Issue 2(2019) 165-174
2. Panayotov, H., Penchev, S., & Kolibarov, D. (2017). Experimental study of canard UAV aerodynamics. MATEC Web of Conferences, 133, 01002.J. Barlow, W. Rae, A. Pope, Low-Speed Wind Tunne Testingl, (John Wiley & Sons, 1999)
3. Bergmann, A., & Hummel, D. (2001). Aerodynamic effects of canard position on a wing body configuration in symmetrical flow. 39th Aerospace Sciences Meeting and Exhibit.
4. ANDERSON, S. B. (1987). A look at handling qualities of canard configurations. Journal of Guidance, Control, and Dynamics, 10(2), 129–138.
5. MCGEER, T., & KROO, I. (1983). A fundamental comparison of canard and conventional configurations. Journal of Aircraft, 20(11), 983–992.
6. John D Anderson Jr, “Introduction to Flight”, Tata Mc Graw Hill-2007
7. Daniel P.Raymer, Aircraft Design.
8. John D Anderson Jr, “Fundamentals of Aerodynamics fifth edition”.
9. GUDMUNDSSON – GENERAL AVIATION AIRCRAFT DESIGN