Twin Fuselage Glider Launch System

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Abstract— In order to improve the payload capability, reduce the bending moments and launch mini rockets and weather balloons, the development of a twin fuselage configuration glider launch system is introduced in our project. Twin fuselage configuration is considered to be advantageous in both aerodynamics and structures. Through this project we evaluate the possibilities for future full-scale aircraft. The flight performance and stability are evaluated by flight test.

Keywords: UAV, Twin fuselage, V- Tail, Aspect ratio, Taper ratio

I. INTRODUCTION

Aircraft design studies have indicated that significant performance improvements can be achieved for UAV by utilizing the novel concept of two fuselages. In general, the benefits afforded by two fuselages are an effective increase in wing aspect ratio and decrease in induced drag, reduced wing structural weight due to a reduced wing bending moment. There are many advantages of twin fuselage aircraft over conventional aircraft as range and payload increase. Our project 'Twin fuselage glider launch system' is an application that could lead to sounding rockets being launched from pilotless aircrafts at high altitudes. It could significantly improve the efficiency of sending weather balloons to a large height to know the weather conditions. It consists of two main fuselages. A platform is located in between these fuselages. Swept back wings are used and tail configuration is V type at 120° outwards. Two propellers are located at the main fuselages which provide the thrust. A key performance parameter for this system is carry efficiency. Distinct advantages of the system are possible reduction in cost, logistic efficiency and high lift to drag ratio platform. The twin fuselage configuration offers the advantage of clean payload area underneath the wing centre section. It reduces bending moments to a large extent. The project goal is to examine the performance advantage and operational aspects. The weather balloons are usually subjected to deviation from the trajectory when launched from ground. But when launched from a high altitude, no deviation would occur. For this purpose, a UAV can be used to take the rockets and weather balloons to high altitudes. This UAV could be capable of carrying this payload. For a UAV with one fuselage would not be able to do this. There comes the need for a UAV with two fuselages with a platform for carrying the payload. When compared to single fuselage UAVs the bending moments produced by payloads could be reduced to a large extent. Moreover, the expenses incurred for this is high. But with the proposed system expenses can be reduced considerably. The maneuverability and stability are quite high for this type UAV. Thus this project has a great scope and leaves many opportunities in research for aspiring aeronautical engineers.

II. PREVIOUS WORKS

DESIGN AND PERFORMANCE TEST OF A TWIN FUSELAGE CONFIGURATION SOLAR POWERED UAV (Xian-Zhong GAO, Zhong-Xi HOU, Zheng GUO Xiao-Qian CHEN)

the payload capability, reduce the bending In order to improve moments and make the accession to near-space easier, the development of a twin-fuselage configuration solar-powered UAV is introduced in this paper. From this paper we could make out the main advantages of twin fuselage configuration i.e., reduction of bending moment and payload capability. We conceived the idea. But we decided to change the source of power. Because consumption solar power source is not reliable at all times. Moreover, the design adopted in this UAV was subjected to deformation in torsional modes. So we thought of reducing the deformation. For that we used tapered wing to reduce wing tip loading. NASA (SPACE TEHNOLOGY GAME CHANGING DEVELOPMENT)

NASA successfully flight-tested a prototype, twin-fuselage towed glider that could lead to rockets being launched from pilotless aircraft at high altitudes—a technology application that could significantly reduce cost and improves efficiency of sending small satellites into space. The one-third-scale twin fuselage towed glider's first flight took place Oct. 21, 2014, from NASA's Armstrong Flight Research Center in California. The towed glider is an element of the novel rocket-launching concept of the Towed Glider Air-Launch System (TGALS). NASA Armstrong researchers are developing the system, which is funded as a part of the Space Technology Mission Directorate's Game Changing Development Program. The TGALS demonstration's goal is to provide proof-of-concept of a towed, airborne launch platform. Distinct advantages are believed possible in cost, logistic efficiency, and performance when utilizing a towed, high lift-to drag launch platform as opposed to utilizing a traditional powered "mother ship" launch platform. The project goal is to examine the performance advantage, as well as the operational aspects, of a towed, airborne launch system. A key performance parameter for this demonstration is carry efficiency is the ratio of weight carried to launch platform weight, where launch platform weight is equal to gross takeoff weight (GTOW) minus weight carried.

III.OBJECTIVE OF THE PAPER

In this project the examination of performance as well as operational aspects of a twin fuselage UAV are carried out. The primary objective of twin fuselage glider launch system is to provide a platform to launch mini rockets and weather balloons. There exist full scale models that can be used for these purposes. But they are towed one. We try to develop a self-propelling one and avoid the use of other aircrafts for towing. Also the aerodynamic performance, stability and maneuverability are examined well. Another objective is to produce a UAV which is capable of carrying more payloads compared to conventional UAV and thereby reduce the cost. This project also leaves many opportunities in research for aspiring aeronautical engineers.

III. .MATERIALS USED AND METHODS FOLLOWED

While designing a UAV there are several material options to be considered. Any design must consider different materials based on durability, machinability and price. While designing weight is also a main factor. The materials used for fabrication of the model are polyurethane foam, Al 6061-T6, depron sheet. The main design parameter is minimum weight. For that high strength to weight ratio materials are required. Incorporation of foam to fill up the volume saves a lot of weight. Aluminium alloy will be used for the main spar. Al 6061-T6 was chosen as the spar material because it has a very good strength to weight ratio. We have used brushless motors. Brushless motor have coils on the inner side of the motor, which is fixed to the mounting. On each of the brushless motors a propeller is mounted. Propellers come in various sizes and pitches. We planned to use 1045 (10 diameter and 4.5 pitch). With same diameter and larger pitch the propeller would generate more thrust and lift more weight but requires more power. One critical factor to ensure stable flight is knowledge of the exact rotor RPM, which in turn will mean a better idea of torque. The Flight line electronic speed controller can be programmed to maintain a constant RPM through the use of a governor mode.

CONCEPTUAL DESIGN

The conceptual design covers all initial design aspects of the aircraft such as configuration, arrangement, sizing, weight and performance. Portability and manufacturability are key factors in concept selection. We found that conventional configurations were good because of its simplicity in manufacturing and controlling. So we opted for conventional configuration. High wing was found most suitable because of its stability and lift. Earlier mid wing was considered. Later it was given up because of its difficulties in manufacturing and portability. Conventional and V tail configuration were the main competitor during the tail selection. Conventional configuration has higher stability and controllability compared to V tail configuration. But V tail was found to have more portability and velocity. It is light weight and offers good stability and control characteristics. It is also easy to design and manufacture. During selection of motor location. Tractor configuration was selected. Because in the case of pusher configuration thrust losses occur due to unclean air. Clean air is needed to produce high thrust in short take off mode. So tractor configuration was the best option. Twin wing and wing mounted motor were avoided because of their complexities. With the above furnished details, the final concept of UAV was developed. The final design consisted of

- a) Conventional fuselage
- b) High wing configuration
- c) V tail configuration
- d) Tractor motor location

PRELIMINARY DESIGN

After finalizing the configuration of the UAV, next step was the detailed sizing and aerodynamic analysis of the aircraft. Considering the thumb rules for aerofoil selection such as maximum lift co-efficient, L-D ratio, maximum thickness we selected an aerofoil SA7036 which is used in gliders.



Then we proceeded to geometric sizing. Firstly fuselage was considered. The sizing was done keeping in mind the propulsion package and wing attachments. Next was wing sizing. Our reference book was Daniel P Raymer's Aircraft Design: a conceptual approach. Based on the selected wing loading the area was found to be $0.47m^2$. Then aspect ratio was selected as 12. Then wing span was found to be 2.2m. From the wing area, tip chord and root chord was found to be 0.235m and 0.175m. We decided to make a swept back wing. The swept back angle was taken as 20° after much iteration. After wing sizing we moved on to empennage. The empennage volume coefficient was taken as $0.005m^2$. Root and tip chord was found to be 0.180m and 0.110m. Aspect ratio was taken as 3. Tail length was found to be 0.30m. V tail is inclined at an angle 120° outwards.

CALCULATIONS

Wing

Based on the textual reference of the book namely Aircraft design: A conceptual approach written by Daniel P Raymer, the exact geometry of the wing was calculated.

Based on the wing loading selected, reference area was found out. For gliders wing loading lies in the range $2.4 - 4.2 \text{ kg/m}^2$. So Wing loading was selected as 4.25 kg/m^2 .

 b^2

Initial weight was estimated as 2kg.

$$\frac{2}{s} = 4.25 \text{kg/m}^2$$
Reference area, S = 0.47m²
Aspect ratio was selected as 12.
Aspect ratio, A.R = $\frac{b^2}{s}$
 $\frac{b^2}{0.47} = 12$
Wing span, b=2.2m
Reference area of wing = $\frac{1}{2} \times (C_{\text{Tip}} + C_{\text{Root}}) \times 1.1 = 0.47$
Taper ratio = $C_{\text{tip}}/C_{\text{root}} = 0.7$
From this C_{ip} and C_{root} was found to be 0.235m and 0.175m respectively.
Aerodynamic chord, $\vec{C} = \frac{2}{3} \times C_{\text{Root}} \times (\frac{1+4\lambda^2}{1+\lambda}) = 0.206\text{m}$
Max C_L of SA7036 = 1.192
Sweep angle, $\Lambda = 20^{\circ}$
 $e=((4.61 \times (1 - 0.045 \times AR^{0.68}) \times (\cos \Lambda^{0.15})) - 3.1 = 0.377$
 $C_{\text{LMax}} w = \frac{C_{\text{LMax}} u}{1+\frac{C_{\text{LMax}} a}{14}} = 1.0978$
Stall velocity, $V_{\text{Stall}} = \sqrt{\frac{2W}{\rho SCLMax}} = 7.89\text{m/s}$
Cruise velocity, $V_{\text{Stall}} = \sqrt{\frac{2W}{\rho SCLMax}} = 1.153\text{m/s}$
 $C_{D,0}$ was found from $C_{d^-\alpha}$ graph.
 $C_{D,0} = 0.135$

Fuselage

Fuselage length = 75% of wing span = 1.65m

Tail configuration

Our tail configuration is V tail. It must be inclined at an angle 120° outward. Because it increases ruddervator effectiveness. We had to find out the root chord, tip chord and tail length. We followed the same procedure as that followed in conventional tail. The procedure is described below.

To find out the tail length •

> Horizontal tail area = 27% of Wing area=0.1269m² Vertical tail area=35% of Horizontal tail area= 0.044m²

Since V tail has only tail inclined at 120°, area was taken as 0.044m²

Aspect ratio was selected as 3. This was done following the historical trends in Daniel Raymers Design book. The tail aspect ratio of various gliders lies in this range.

Aspect ratio, AR= $\frac{b^2}{s}$ =3

From the above equation, Tail length, b=0.3m

Tail area =
$$\frac{1}{2} \times (C_{Tip} + C_{Root}) \times b = 0.04$$

 $(C_{Tip}+C_{Root})=0.27$

Taper ratio=
$$\frac{CTip}{CRoot} = 0.6$$

Solving the above equations $C_{Tip and} C_{Root}$ was obtained as 0.110m and 0.180m respectively.

Tail moment arm, TMA =
$$\frac{2.5 \times MAC \times 0.2 \times WA}{HTA}$$

Where MAC is mean aerodynamic chord, WA is wing area, HTA is horizontal tail area.

Substituting all values in the above equation we get TMA= 0.38m

ie, Tail must be placed at a distance 0.38m from trailing edge of wing.

Control surfaces

Now, all the dimensions required to determine the control surface geometry have been acquired. Based on the data collected about aircrafts operating at low speed with high aspect ratio, the empennage surfaces should have 30% of chord and at least 40% of span dedicated to control surfaces.

Ailerons

Chord(% of wing chord)	Chord(m)	Span(% of wing span)	Span(m)
25	0.05125	45	0.495
30	0.0615	50	0.55

Table No.1	- Aileron	details
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Ruddervators				
Chord(% of wing	Chord(m)	Span(% of wing span)	Span(m)	
chord)				
25	0.03	90	0.27	
30	0.04	95	0.28	

Table No.2 - Ruddervator details

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	Chord(m)	Span(m)
Ailerons	0.04	0.55
Ruddervators	0.03	0.28

Table No.3 - Final Sizing

DETAILED DESIGN

After the preliminary design is completed, the detail design phase was started. All systems and components were designed, selected and integrated. We started with the wing. The rectangular rods were selected as spars. The spars are placed where maximum camber is present ie,at $1/3^{\text{rd}}$ of chord. The spars could be kept there by making a slot along the entire length of wing from root to tip. Later we learned that that alone would not serve the purpose of giving strength. So we thought of making box spar. Spars could be added along the leading edge and trailing edge so that the entire spar would form a box like structure. Then came the design of fuselage which was challenging. Because it has to house the receiver, circuitry, propulsion package. Also wing was to be attached. In order to attach the fuselage to wing a slot was to be made. So we thought of making a female airfoil template. Using this slot could be made on the top surface of fuselage and wing could be attached there. Then we thought of giving strength to fuselage. For that purpose, we planned about placing a rectangular rod below the slot made by female template. This could serve many purposes like attachment of motor fire wall at the front end of the rod and wing tail at the aft end. The design of the empennage focused on simplified the structure as much as possible to reduce the weight. We decided to use polyurethane for the tail fabrication. It needed an additional strength. At the same time, it should be attached to the end of fuselage. So we planned to insert a cylindrical rod at the root of the tail. The V tail has been designed relatively simple because it does not experience twist and stress like the main wing. After that we planned how to make ailerons, ruddervators. After the detailed design we moved on to fabrication. The materials used were polyurethane foam (for wing, fuselage and tail) and depron sheet (for ailerons, ruddervators).

DIMENSIONAL CHARACTERISTICS

The dimensions of main aircraft parts are documented below. The following dimensions were finalized after integration test and were then strictly implemented during the manufacturing phase.

FUSELAGE		
Length	1.65m	
WING		
Area	0.47m ²	
Span	2.2m	
Root chord	0.235m	
Tip chord	0.175m	
Aspect ratio	12	
Aileron Length	0.56m	
Aileron chord	0.04m	
Dihedral	0	

Sweep	20°	
V Tail		
Span	0.30m	
Area	0.04m ²	
Root chord	0.180m	
Tip chord	0.110m	
Aspect ratio	3	
Ruddervator length	0.28m	
Ruddervator chord	0.03m	
Inclination	120° outwards	

Table No.4 - Dimensional characteristics

IV.TECHNICAL ANALYSIS

The technical analysis of a completed UAV is the outline of debut test flights. It dealt with analysis of stability, handling and aerodynamic performance.

FIRST TEST FLIGHT

All the group members were anxious about flight. Because new innovations were incorporated in the UAV. We were curious to know the results. All components were assembled together and connections were done. The UAV's conditions were checked properly by the team at the site. Then control surface's neutral points were configured on the remote control. The UAV was to be thrown by a scientist in NAL with a lot of experience in piloting and throwing UAV. It was piloted by an officer in HAL with a great experience in piloting with UAVs. The preliminary checks were performed once more. The UAV became ready for launch. The pilot gave the thrower a confirmation nod. The throttle was maxed out and the thrower threw the UAV with ease. The UAV flew straight upwards into the air. We all felt greatly relieved. Our hard work did not become futile. After 2 minutes of circling overhead and the evaluation of control surface limitations, performance and maneuverability, the UAV was landed into the wind using the deep stall method. Fortunately, there were not any damages. Thus the first flight test turned successful.

POST FLIGHT EVALUATION

- The wind speed was quite high. However, UAV could be handled well because of the care given for the stability matters.
- The UAV's centre of gravity was oriented properly. The effect was seen in the performance of the aircraft and pilot's ease of control.
- There was no need for adding more weights to add to dynamic stability. There was enough stability.
- The hand launch was extremely successful.
- The more experienced pilot said that the design was perfect.

IV. RESULTS AND DISCUSSIONS

The design, the fabrication and the flying of twin fuselage glider launch system were done successfully. The operational and performance aspects were clearly examined. The model possessed good stability. During flight it could recover from pilot errors and environmental disturbances. The maneuverability was found to be good. It could be handled with ease. Also hand launch was tested and the result was good. The model found it difficult to align with the runway. But there were not any damages to parts of UAV. The design applies the principles of fluid and aerodynamics to reduce drag and increase lift. Material mechanics were applied to design an extremely light aircraft that will still be able to withstand any load that it experiences during a normal flight. The aircraft was also designed with a taper wing to ensure that it is highly stable and it recovers from pilot error and environmental disturbances. The maneuverability was also good. Throughout the design process many challenges were overcome to improve upon the efficiency of the design and so with much confidence this design will be highly competitive. Another lesson learnt was lot of stuff which is studied in analytical equations and formulations, does not apply to ground realities. Also we could make out that twin fuselage configuration could carry more payload compared to conventional fuselage configuration. Hand launching was found to be good. The main problem we found was the difficulty faced by UAV in aligning with the runway. It was also sensitive to damages. We believe that this is a great topic of great significance and owns a great scope for research.

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Final model

VI. ACKNOWLEDGMENT

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