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Design and performance analysis of unmanned aerial vehicle (UAV) to deliver aid to the remote area

Rafi ur Rahman[1], Muhammed Hasnain Kabir Nayeem[2], Mosarruf Hossain[3], Md. Roman Hossain Fazlah Rabby[4]
[1-4]Military Institute of Science and Technology
rafirahman57@gmail.com[1], muhammednayeem753@gmail.com[2], mosarruf.shawon@gmail.com[3], romanrabby49@gmail.com[4]

Abstract

The Small Unmanned Aerial Vehicle is playing an increasingly significant role in modern military and civil arena. The list of potential uses is now rapidly expanding to encompass a broad range of other activities, including aerial photography, surveying land and crops, communications and broadcast, monitoring forest fires and environmental conditions, and protecting critical infrastructures. An Unmanned Aerial Vehicle named 'Mohapotongo' has been designed with the capability of carrying medical aid to remote areas. The Mohapotongo is an advanced, durable, lightweight aircraft designed to carry 700gm of payload covering a range of 20km.Via the autonomous system in Mohapotongo, it can gain information about the environment, work for an extended period without human intervention, move either all or part of itself throughout its operating environment without human assistance and its building structure enable it to carry easily. The Mohapotongo is a canard configured aircraft with the capability of hand-launch or pod launch and is incorporated into the battery powered the electric motor. The overall design process has been done using system engineering process. This paper presents the design methodology, performance analysis, and manufacturing process of the UAV Mohapotongo.
Keywords: Aircraft Design, UAV.

1. Introduction

In recent years, the concept of the small unmanned aerial vehicle (UAV) has become popular for both civil and military purposes. Unmanned air vehicles were once the stuff of rumor and legend, identified in the press as new and mysterious “New shapes in the sky”, declared the headlines at one time in the recent past.[1] Now they seem to be commonplace, on the battlefield at least, where they are seen carrying out surveillance missions and deploying weapons with great accuracy. They are now truly the solution to some of the dull, dirty and dangerous tasks for which they were first proposed. Apart from military applications, there are many jobs to be performed in commercial and government applications in surveillance, monitoring, and troubleshooting in the fields of utilities, maritime rescue, borderline inspection and excise and agriculture to name only a few. Search and rescue (SAR) involve locating, rescuing, and medically stabilizing victims trapped in hazardous spaces. As such, SAR operations are of great importance in disaster situations like earthquakes, hurricanes, tsunamis, or terrorist attacks. Rescue workers have approximately 48 hours to find trapped survivors, otherwise the likelihood of finding victims alive drops substantially. Traditionally, such missions have been performed by human teams, however, disaster environments have been known to be very difficult to access by rescue workers due to the potential presence of asbestos dust, poisonous gases, hazardous materials, radiation, or extreme temperatures. UAV, on the other hand, can bypass the danger and expedite the search for victims immediately. Thus, rescue UAV provides a promising solution to assist rescue workers in many aspects of SAR operations. For instance, rescue UAV can reduce the chance of injury to workers by entering unstable structures, increase the speed of response, and through multiple cameras and sensor fusion, extends the reach of rescue workers to regions that would otherwise have been inaccessible.
The main aim of this project is to design a UAV which can perform in such kind of situations, and throughout the paper, we describe the design, fabrication and building process of it.

2. Conceptual Design

Mission requirement

Mohapotongo has to be designed in such a way that it must be capable of flying longer time with the maximum amount of payload and have the ability to release the payloads or aid supply in the targeted area. To make it more compatible and ready to fly, it should have the ability to hand launch or pod launch. The aircraft has to be designed considering the placement of the payload.[2] The following table represents the mission requirements for the UAV.

Table.1. Mission requirement

Payload carrying capacity	700 gm
Cruise speed	60 m/s
Stall speed	8 m/s
Maximum Take-off weight	2.5 kg
Endurance	45 min

Design Explanation

The first and foremost task of designing an aircraft is to translate the mission requirements into design requirements. The requirement of short take-off is satisfied by increasing the amount of thrust and wing loading capacity. A compartment for the payload is placed on the bottom of the main body with a safe falling parachute mechanism so that maximum amount of payload can be carried. Payload has a compact size so that it can easily attach to the main body. For High glide rate of the wing, the plane can travel a long time with less power. The dropping mechanism and safe falling mechanism of the payload are optimized by using a handmade parachute of elliptical type. The following table represents the derived design parameters after primary estimation.

Table.2. Derived Design Parameters

Wing load capacity	2.705 g/in^2
Total wing loading	1964.38 gm
Thrust	2420 gm
Battery	4200 mAh 4 cell
Peak amp	23-23 amp

3. Detail Design

In this phase, each component of the mohapotongo has been designed with precision and different parameters are calculated.

Wing

Fixed-wing aircraft can be built with many wing configurations. We used straight, high and cantilever wing configuration as it is easy to build and carry more of the airplane's weight farther inboard. High wing configuration makes the aircraft more stable.[3] Cantilever configuration is self-supporting. All the structure is buried under the aerodynamic skin, giving a clean appearance with low drag. The winglet is used to reduce the wingtip vortices which allows the UAV to fly longer period.

After analyzing the historical trend and calculating the design parameters for wing following values were found.

Table.3. Wing parameters

Wing angle of attack	7 deg
Wingspan	71.600 in
Wing area	484.206 in^2
Wing load	2.513 g/in^2
MAC(mean aerodynamic chord)	6.823 in
Aspect ratio	10.588
Root tip sweep on winglet	3.624 deg

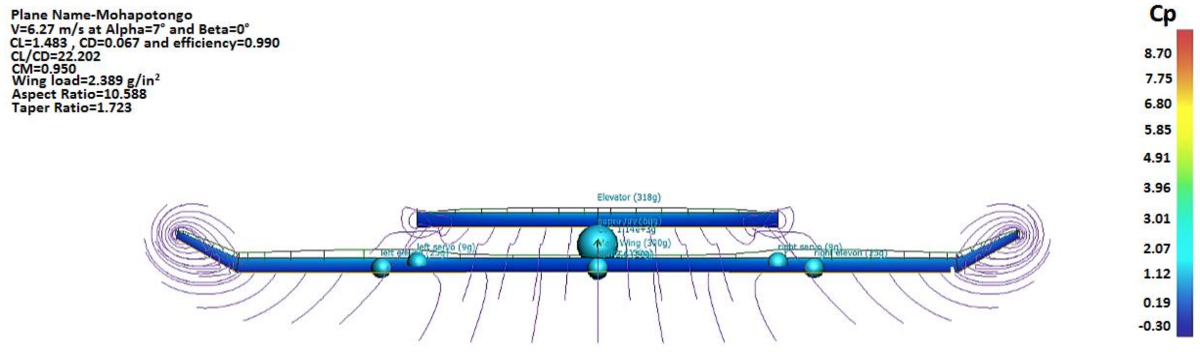

Fig.1.Flow over the wing

The analysis shows flow is uniform over the wing and at the tip due to winglet vortices is not too significant to redesign the wing. Depron was used as the main material of the wing and aluminum pipes are used as spars.

Airfoil selection

After deriving the wing parameters, the airfoil for the wing was selected. Depending on the trade studies three airfoils were selected for more extensive analysis. The selected airfoils were Eppler 210, Clark Y. NACA 23021. Then these three airfoils were analyzed in XFLR software at the required flight condition.When a stream of air flows past an airfoil, there are local changes in velocity round in aerofoil, and consequently changes in static pressure, in accordance with Bernoulli's Theorem.[4]Clark Y airfoils were selected as the change of pressure coefficient over the airfoil was uniform. The ratio of lift-to-drag is a measure of the aerodynamic efficiency of an airfoil.[5]The value of Cl/Cd of the Clark Y airfoil is higher than the other two. At last, the Clark Y airfoil was analyzed in the Ansys software to get the clear view of the pressure and lift distribution.

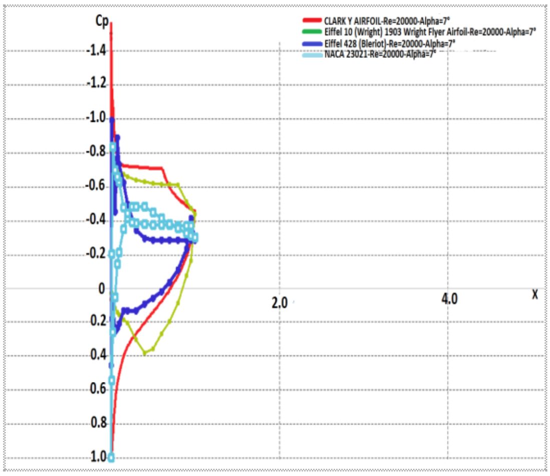

Fig.2. C_p vs Distance curve

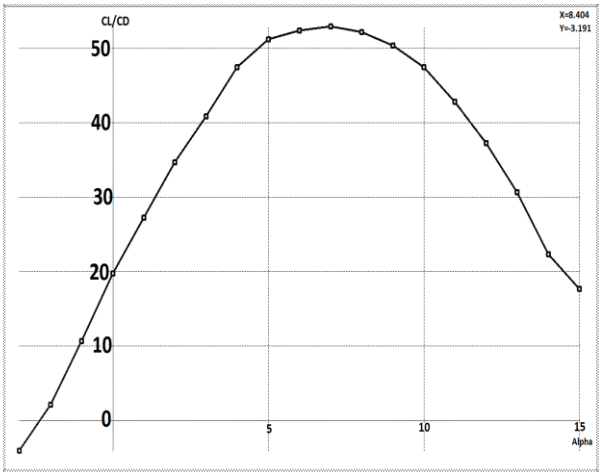

Fig.3. Cl/Cd vs alpha

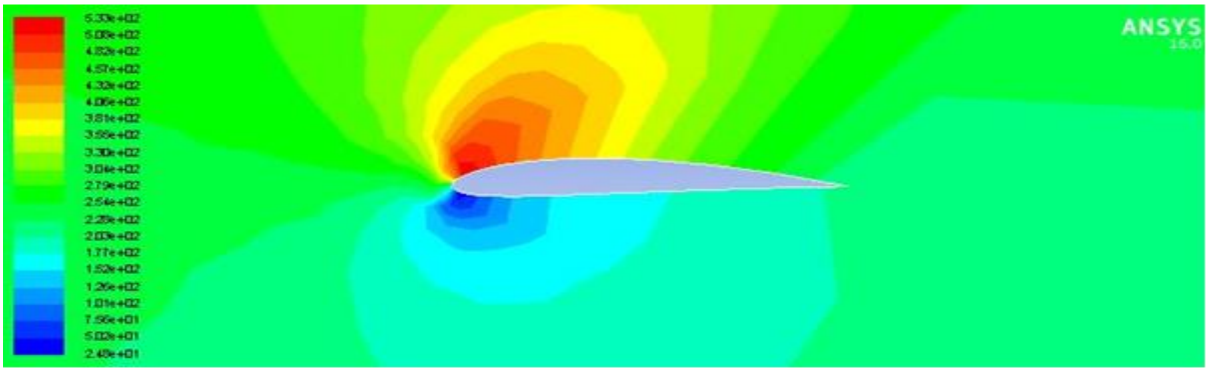

Fig.4 Pressure distribution over Clark Y airfoil

Fuselage

The fuselage is constructed as the box configuration as the main advantage of box structure it can be built easily. Both the compartment for the avionics and another integrated system can be placed in the specific place. Another advantage of using the box mechanism is that the dropping mechanism can be placed underneath the main body perfectly and this configuration is more stable and has good strength.

Table.4. Fuselage configuration

Overall length	50 inch
Width	3 inch
Height	3.50 inch
Fuselage construction	square

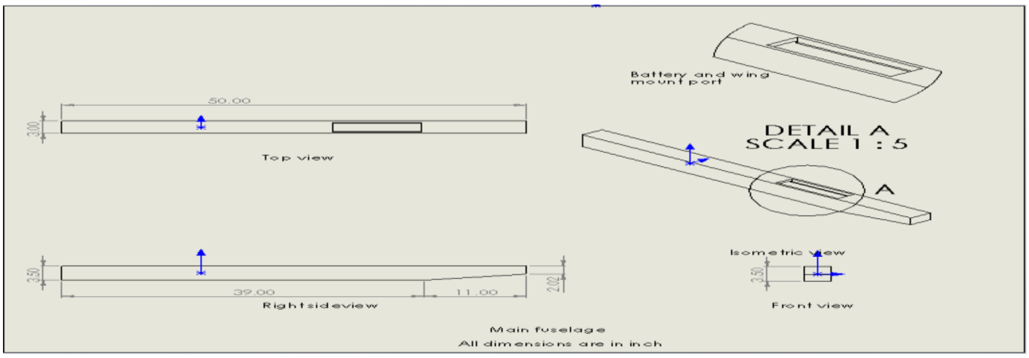

Fig.5 Fuselage Dimensions

Tail

Instead of using conventional tail configuration we optimized elevon mixing system. Elevons are aircraft control surfaces that combine the functions of the elevator (used for pitch control) and the aileron (used for roll control), hence the name. They are frequently used on tailless aircraft such as flying wings. An elevon that is not part of the main wing, but instead is a separate tail surface. Elevons are installed on each side of the aircraft at the trailing edge of the wing.The primary function of the horizontal tail is longitudinal trim, and then longitudinal stability.The fore plane is capable of satisfactorily fulfilling both mission requirements. When moved in the same direction (up or down) they will cause a pitching force (nose up or nose down) to be applied to the airframe. When moved differentially, (one up, one down) they will cause a rolling force to be applied. These forces may be applied simultaneously by appropriate positioning of the elevons e.g. one wing's elevons completely down and the other wing's elevons partly down.

Propulsion

From the analysis, it is found that 2 kg thrust is required to operate Mohapotongo. To provide this thrust one Sunnysky motor is used with the 13*4.5 folding propeller.[6] This motor is able to produce 20% more thrust than we require. The motor is installed on the back as pusher configuration, so there is no downwash effect on the wing.[7].And the pilot has clear view without any disturbance. Moreover, a pusher type of propulsion system is more stabilizing than the puller one. The absence of front engine allows special equipment (radar, AUV cameras) to be efficiently installed in the fuselage nose. A pusher may have a shorter fuselage and hence a reduction in both fuselage wetted area and weight. A pusher needs less stabilizing vertical tail area and hence presents less weathercock effect; at takeoff roll, it is generally less sensitive to crosswind.

Landing Gear

No landing gear is used in the aircraft. As the load is carried on the bottom surface and the aircraft is capable to hand launch so no landing gear is used for taxing the aircraft. It also provides us a reduction of total weight. Skate system is installed under the body so that it can land easily in any place.

Payload

The payload is mounted externally so that the navigation system can have enough space on the aircraft to fit perfectly and as the payload installed on the outside of the aircraft so it is easy to drop the payload on the specific zone easily. An elliptically shaped parachute is used on the payload for easy dropping with less damage.

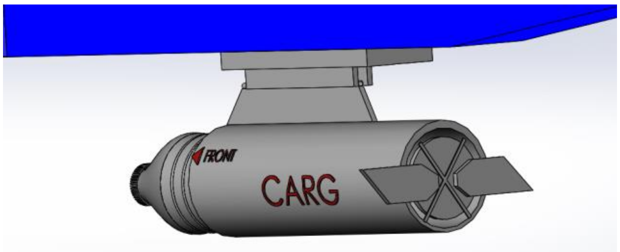

Fig.6. First parachute deploy mechanism

Canard configuration

The canard avoids deep stalling effects. This is interesting to note that about 23% of all world aircraft crashes relate to a deep stall.[8] The main reason behind that the main body located in front of the wing, so the wing wake does not influence the canard aerodynamics characteristics.

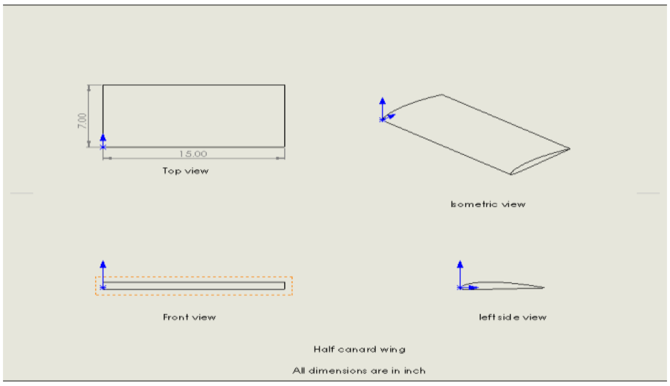

Fig.7 Detailed Drawing of Half Canard

4. Navigation System

Antenna

For controlling the UAV a 433 MHz UHF system was used. In TX half wavelength UHF antenna was used and for RX 433 MHz 120° v antenna was fabricated manually by analyzing RSSI. For video transmission, 1.2 circular polarized antennae in TX and omnidirectional patch antenna in RX with antenna tracker was incorporated.[9]

Auto-pilot system

An 8-bit autopilot system based on Atmel's ATMEGA2560 and ATMEGA32U-2 chips was used for processing and USB functions respectively.[10]

Arducopter APM 2.6 board of 3dr technologies which comes with Atmel’s ATMEGA2560 and ATMEGA32U-2 chips was used for processing and USB functions respectively. It also packs some very useful and high-end sensors like 3axis gyro, barometer, accelerometer and 4-megabyte data flash chip for autologin. This log gives us the opportunity to analyze our flight and find out the faults by log analyzer software. A U-box M8N GPS was used for autonomous operations.

For configuring and uploading mission on the autopilot we used Mission planner, APM planner, and Tower software. As being an unconventional configuration the algorithms were created manually. We used power filters for undisturbed and continuous power supply to the autopilot and the GPS.

5. Final Design

After all the calculation and estimation was completed a SolidWorks model of the Mohapotongo has been done. The following figure shows the front, right side, top and isometric view of the UAV.

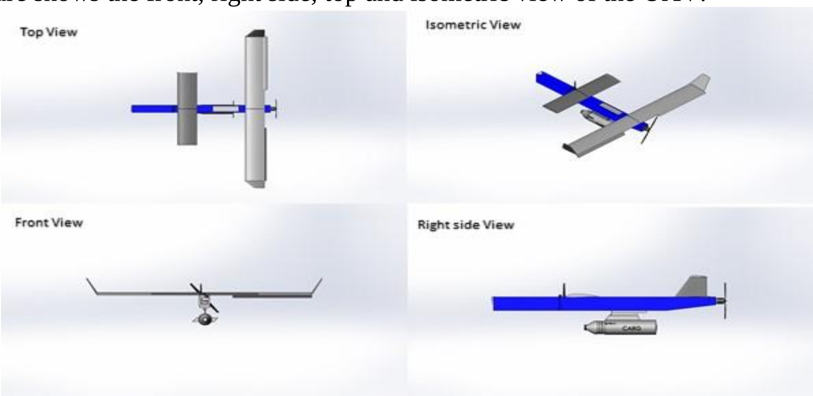

Fig.8 Final Solidworks model of Mohapotongo

After the design work completed the UAV was manufactured using ‘Depron’ which is very lightweight but has the high strength capabilities. Aluminum bar and balsa wood were used for structural support of the UAV.

Fig .9 Final Manufactured Model

6.Result Discussion

System engineering methodology is used to gain the final configuration of mohapotongo.As shown in Fig.8 and Fig.9 the final configuration satisfies the design requirements and mission requirements. Fuel efficiency is a key factor to evaluate the performance of this aircraft. Based on static stability design, high lift to drag ratio and pitch trim are achieved at cruise condition, which increases the glide rate and endurance and reduces the battery using rate and buffet characteristics are also satisfied. During the test flights, the dropping mechanism was severely tested.

7. Conclusion

The unmanned aerial vehicle is one of the magical inventions of this modern world. The need for assistance of UAV’s in uncertain situations is increasing rapidly. To assist the human beings in surveillance and rescue mission a customized UAV named ‘Mohapotongo’ was designed and manufactured. It has the ability to carry a payload of 700gm with the capability to cover the range of 10km. The maximum take-off weight is 2.3kg. One commercially produced sunny sky motor was used for the propulsion system. The payloads are carried externally. Mohapotongo has an unconventional design as it is a tailless UAV incorporated with canard system. Arducopter APM 2.6 board of 3dr technologies which comes with Atmel’s ATMEGA2560 and ATMEGA32U-2 chips was used for processing and USB functions respectively. Depron was used as the primary material for construction due to its high strength to weight ratio and commercial availability. Mohapotongo has undergone several test flights. In future, thermal cam, night vision cam and motion detector will be incorporated with the Mohapotongo in order to detect and rescue human beings from unwanted situations. This paper represents the design methodology and the specifications of the Mohapotongo.

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