International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Design And Development of Man Portable Back Packable Multi-Purpose Drone

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Abstract*: This report mainly presents the concepts, design and analysis of a 'Man Portable Back Packable Multi Purpose Drone (MPBPMD)' which has many applications in different areas for different operations. The technology employed in the design of this 'MPBPMPD' is adapted from the mechanism of tilt rotor, which can be fabricated as rotor MAV, similar to helicopters and hovercrafts. The main objective of this aircraft design is to provide payload bay which can be installed with multiple payloads like a camera which can be used for surveillance or a speaker to control the animals in the reserved forest, etc. The MPBPMPD will be equipped with Auto pilot for a better operational control and navigation of the aircraft even at the places with less Launch distance using its VTOL capability. The wing attach/detach mechanism technique is also used to provide the aircraft with better portability. The complete aircraft should fit in a backpack, so that the complete model can be carried easily for better portability.

Keywords*: Micro Unmanned Air Vehicle (MUAV), Tilt-rotor, VTOL, Portability, Design, Wing attach/detach.

I. INTRODUCTION

The basic concept of micro sized unmanned aerial vehicles or (MAV) has started increasing interest over the past few years for military applications. In the year 1992, RAND report for DARPA[2] stated that the great use of micro UAVs for the wide range of military applications. Firstly, UAVs are autonomous, the main motto is to remove human for the regular wars and basic human casualty

Basically the MAVs have wide arch range of coverage in military operations including the difficult task like fire control, deflection of intruders, border patrol, traffic surveillance and riot controls[3]

Today's piloted military aircrafts are basically equipped with high end technology in order to protect and safe guard the life of pilot which increases the cost and weight but most UAVs can be easily configured for some particular missions which carries the simple hardware system for the completing the mission. The UAVs can be lighter and cheaper because they don't carry life supporting system. Recent developments in the UAV field like the cargo carrier drone created by BOIENG show that UAV s are capable of doing dangerous, heavier and complex works very efficiently. So in order to make them more efficient we have incorporated VTOL mechanism.

A. Classification of UAV's

UAVs are basically classified into six functional categories

- Target and decoy
- Reconnaissance
- Combat
- Logistics
- Research and development
- Civil and commercial UAVs

B. Objectives

The primary objective of the design is to develop a UAV which can be operated from any location with very less space to take-off and land.

- The second objective is should operate at moderate to high speed for better time management.
- The third objective is that the model shall fit in a back pack of size 2.5ft x 1.5ft x 1ft.

Apart from the above aspects, it shall be easy to operate and handle.

C. Scope of the work

The UAV developed shall be used for various purposes like Food delivery, Blood Delivery, First aid kits, pesticide Spraying, etc. It shall be

II. METHODOLOGY

UAV must be a VTOL aircraft since less space is required for landing and take-off. But, an aircraft with VTOL will consume lot of energy and are slow when compared to that of fixed wing aircraft. Hence there was a need to integrate both and produce a hybrid aircraft which operated as VTOL along with fixed wing aircraft.

V-22 osprey and F-35B (JSF) are examples of VTOL and fixed wing.

A. Folding Mechanism

The main motto of this technique is for the portability a new technique is opted in which the wing will divide into two equal halves. So that the space required for the wing will be reduced which is easy to carry. To achieve this, two mechanisms were studied Hinge Mechanism and spring mechanism.

Revised Manuscript Received on December 30, 2019.

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After comparing both the method, Hinge mechanism was selected over spring mechanism as folding technique. In this, a hinge made of Plastic fiber is fixed to the root end of the wing which helps in folding them about the hinge point. The folding mechanism suggested is given below in Fig.1

Fig. 1.Hinge Mechanism

B. Tilt Mechanism

The main motto which should not exceed the weight, then we finalized the top three ideas and started the evaluation process by considering all the factors which effects on the design stage. The comparison and rating of these mechanisms are Table is given below.

Table- I: Comparison of Tilt Mechanism

NAME	L Type Mechanism	Quad Tilt Rotor Mechanism	Wing Spar Mechanism
Structure and components	6	8	8
Functions	9	8	6
Material used	8	9	10
Weight	10	8	5
Strength	8	8	10
Placed to b fixed	9	6	6
Fabrication	10	6	6
Outcome	10	7	5
Pros and cons	8	6	4
TOTAL	78	66	60

III. DESIGN

The Design is a cyclic process [1] and the process employed in design of the aircraft has been given in Fig.2

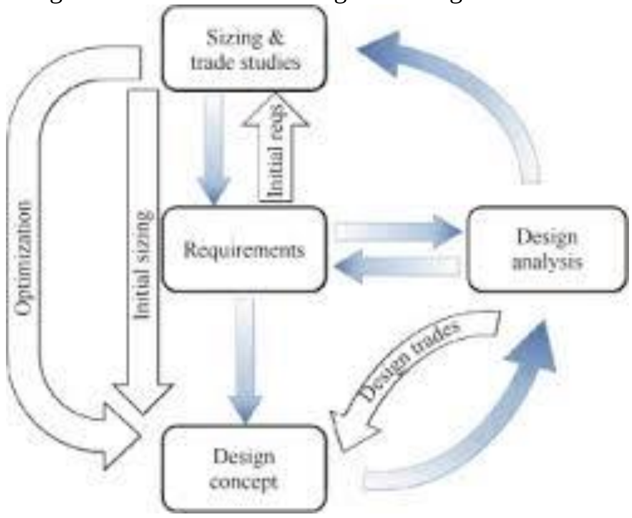

Fig. 2.Design Process

A. Weight Estimation

Weight estimation is done on the basis of the maximum payload which the model should able to carry. The maximum payload weight is considered as 0.35 kgs. The weight estimation table is given below in

Table- II: Initial weight estimation

S. No	Components	Quantity	Weight (gm)
1	DC brushless motor	2	150
2	ESC	2	50
3	Servomotors	2	50
4	metal gear servo	2	100
5	2200mah lipo battery	1	200
6	servo extension wire	2	50
7	Others	-	100
8	Structural Wt	-	750
9	Auto pilot	-	200
10	Payload		350
		TOTAL (gms)	**2000**

B. Airfoil Selection

According to our requirements the airfoil should generate high lift and low drag and thickness to chord ratio should be between 12% and 14% of chord.

The airfoil should have high C_{lmax} value and C_m value close to zero. The variation C_L with respect to angle of attack and C_d should be smooth for better aerodynamic characteristics of wing. After considering all the requirements we have selected HAM-STD HS-1 712 airfoil. The aerodynamic performance characteristics of this airfoil are given in Fig 3 and Fig 4 respectively.

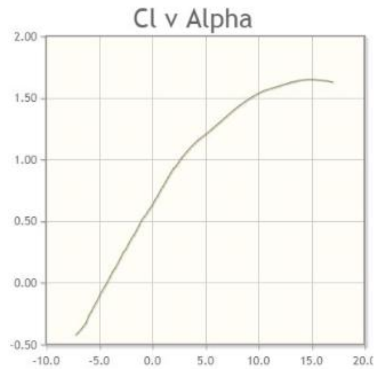

Fig. 3.C_l/C_d v/s AoA Curve

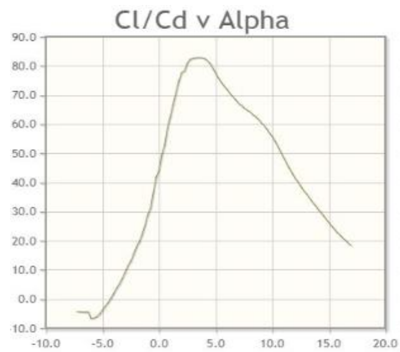

Fig. 4.C_m v/s AoA Curve

C. Wing and Empennage Design

For typical RC planes, wing aspect ratio differs from 4 to 8 and for that of tail is varies between 2 to 4[1]. So, we have calculated the area of the wing and tail required for different aspect ratios and finally the feasible value is selected. The wing and tail dimensions achieved are given in Table III

Table- III: Wing and tail dimensions

Geometry	Span b (m)	Chord C (m)	Area S (m^2)	Aspect ratio (AR)
Wing	1.574	0.192	0.223	6
Horizontal Tail	0.37	0.12	0.045	3
Vertical Tail	0.26	0.09	0.022	3

D. Drag Calculations and Power plant Selection

Total drag is calculated using the formula

$$D = 0.5 * rho * V^2 * S * C_d$$

Here, coefficient of drag (C_d) is the sum of coefficients of frontal area drag (C_{df}), induced drag (C_{di}) and skin friction drag (C_{df}) for complete aircraft.

The total drag of the aircraft at a speed of 13 ms^{-1} was 9.57 N

The thrust produced by the motor must be more than the drag of the aircraft for sustained flight. The power consumption must also be less. But for the vertical take-off, the thrust must be sufficient to lift the weight of aircraft. Hence, two motors have been selected which consume less power when compared to one big motor. The variations of thrust required with respect to the velocity are plotted below in Fig. 5

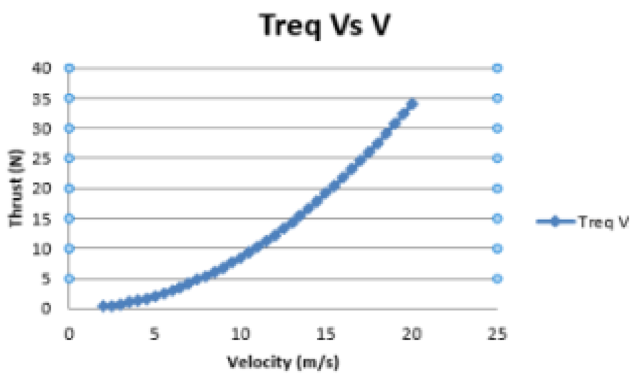

Fig. 5.Variation of Thrust Required versus Velocity

1400kv Racestar motors were selected which gives a thrust of 1.4 kg each.

IV. MODELING AND ANALYSIS

A. Modeling

Generally, a model is intended to represent the physical problem. The model represents physical problem virtually which can be simulated to predict various effects of given loadings. CATIA V5 was used to generate a 3D model and measured inertial properties of the complete aircraft. For this , each and every component is assigned with its material properties. The model created and its inertial properties are given in Fig. 6 and Fig 7 respectively.

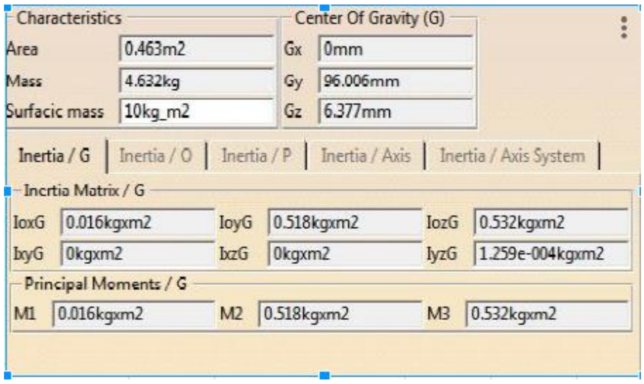

Fig. 6.Inertail properties of the aircraft calculated in CATIA V5

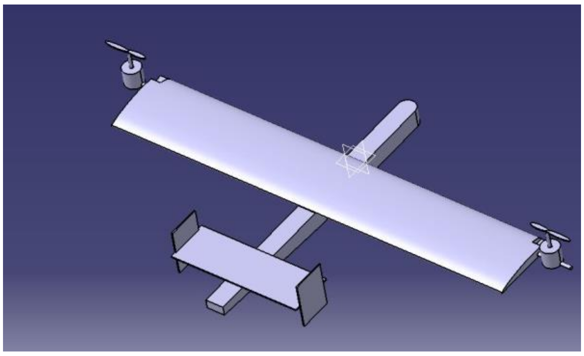

Fig. 7. Final design outcome in CATIA

B. Structural Analysis

Structural strength is important for any aircraft to sustain the forces acting on it during the flight. The wing part of the MAV is considerably facing more forces acting on it and to calculate its structural strength, its structural analysis is done using ANSYS software.

The aircraft wing is analogous of a cantilever beam. One end is attached to fuselage and the other is set free. The deformation at free end and reaction force acting at fixed end are analyzed along with stress developed in wing.

The loading for this model is initiated from the aerodynamic loading of the wing through FSI module in work bench as mentioned by T Sai Kiran Goud[6]

The contours of deformation and stress are given in Fig 8 and Fig 9 respectively.

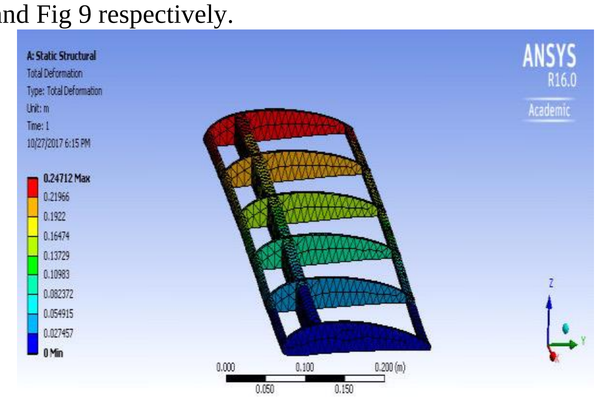

Fig. 8. Deformation Contour for wing

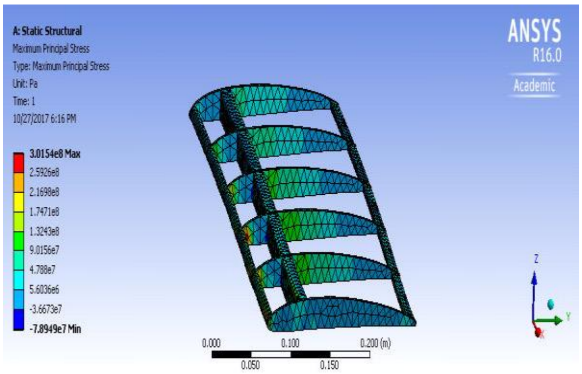

Fig. 9.Contours of maximum principal stress

C. Fluid Flow Analysis

To validate the aerodynamic characteristics of the aircraft, CFD analysis was done on the complete aircraft[4]. The flow conditions considered are given in Table IV.

Table- IV: Fluid Properties and Flow Conditions

S No	Fluid or Flow Property	Value
1	Density	1.225 kg/m^3
2	Pressure	101325 Pa
3	Temperature	300 K
4	Viscosity	1.78*10^5 N/ms
5	Velocity	13 ms^{-1}

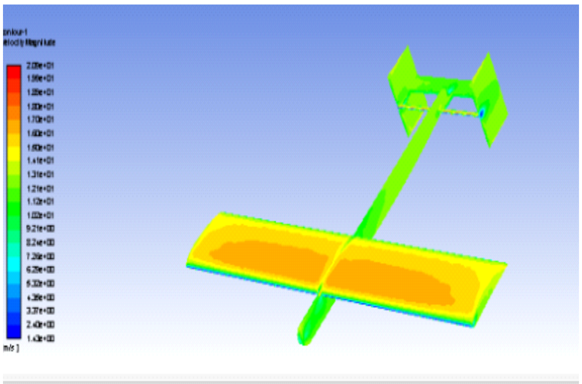

Fig. 10. Velocity contour

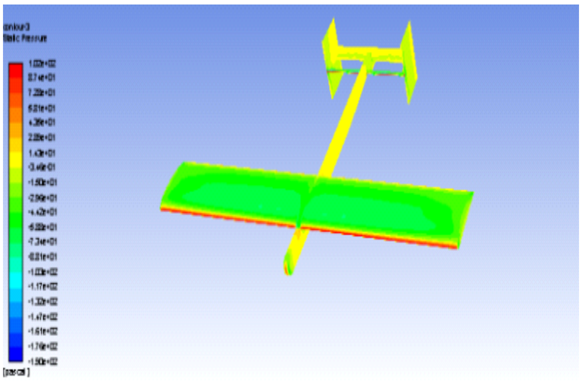

Fig. 11. Pressure Contour

V. RESULT AND DISCUSSION

The results obtained from the initial sizing were compared to that of the computational analysis.

- The lift generated by the wing at a speed of 12 ms^{-1}, as calculated from the CFD is 21 N which is sufficient for the aircraft.
- The drag predicted using CFD is 9 N which is close to the value manually calculated.
- The ultimate stress value for Balsawood is 3.8 GPa. The maximum stress occurred was 0.3GPa which is within the limit of operation. Hence, the structure is compatible and can withstand all the loads.

VI. CONCLUSION

Based on the calculations and the results obtained, it can be noted that the model will fit into a box of specified dimension i.e., 2.5ft x 1.5ft x 1ft. The VTOL mechanism reduces the landing and take-off length to less than 10 m. the wing area is sufficient enough to lift aircraft at a cruise speed of 13 ms^{-1}.

The work done is only a part of the project as there are more aspect of the design to be calculated which includes the stability analysis, fabrication and flight testing. This includes the cost analysis of each model to be produced.

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