Design and Analysis of Pesticide Spraying UAV

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Abstract— **Thispaper attempts to provide a systematic design procedure for the concept model of a pesticide spraying UAV. Avionics selection is explained along withCAD modelling using CATIA V5 and analysis using ANSYS 18.1 software. Finite element method is used to perform static structuraland modal analysis on the frame. Results are obtained for total deformation and equivalent stress. The UAV is to be 3D printed with ABS filament. The payload for the concept model is 1.5kg and diagonal dimension is 678 mm.**

***Keywords*— UAV, FEM, FEA, CATIA, ANSYS, ABS, Quadcopter**

I. Introduction

The impact of technology in agriculture is a positive trend, as it is the solution to feed the teeming population. Food security is a question that needs to be addressed, in the background of environmental degradation, pollution, and water scarcity, and an effective solution is a high priority. This is where usage of UAV can guarantee a sustainable solution.

Pesticide spraying is vital among many agriculture processes. While proving to be a boon for farm productivity, chemical pesticides have been fatal for human health and environment. Conventional spraying methods require human labour wherein they turn a blind eye towards the use of personnel protective equipment.Pesticides can enter the body through inhalation, ingestion, or absorption by the skin and eyes. It also turns out to be cumbersome when spraying in plantations with uneven terrains like in tea or in muddy paddy fields.UAVs in agriculture can ignite a big change in improving the efficiency of agriculture. UAVs are alternative to lack of skilled human resources and also to other heavy machines and tools. To a very good extent, it is a cheap and economical way to manage farming.

The frame of the UAVmust be made of very light material.Materials such as aluminium and wood are light butaluminium cannot be used because of its inability to absorb vibration from the motors whereas wood could easily be destroyed by insects and weather conditions[1]. A plethora of technological advancements in rapid prototyping industry made industrial 3D printers affordable, available as per user convenience. By using 3D printing technology, drones can be fully customized, printed using various materials such as PLA, ABS, ABS-PC, Carbon fibre, etc. This is cost, time and user effective procedure[2]. ABS is generally used for drones owing to its strong, durable and flexible nature [3].Thetwo possible configurations for most of the quadcopter designs are “+” and “×”. An X-configuration quadcopter is considered to be more stable compared to + configuration, which is a more acrobatic configuration[4]. Stability can be further increased by providing internal baffle plates to reduce sloshing of the spray material load during flight[5]. Forces acting upwards on the UAV should be double the maximum weight [6]. It is also important to check the effect of these forces on the frame before manufacturing. FEM is used to analyse the UAV frame and obtain results for various boundary and loading conditions on software [7].

II. Design

An easy way to start designing a UAV is by estimating the gross weight. The concept model has a payload of 1.5 kg. A quadcopter with gross weight around 4kg is capable of producing enough thrust to lift the model. Quadcopter is a type of UAV which is made of four rotors positioned equidistant to the centre of mass of the device in order to generate lift and manoeuvrability. The designing approach for aforesaid concept model is as follows.

A. Avionics Selection

It includes selection of propulsion system (motor, propeller, battery) and flight controller. Following formulae are used to determine required avionics specifications:

$$Thrust = \frac{2 \times Weight}{4}$$

$$Thrust = \frac{2\pi \times r^2 \times \rho \times P_{motor}}{3}$$

$$Battery\ mAh = \frac{Time\ of\ flight \times current \times 1000}{60}$$

Where, r is radius of propeller, $P_{motor}$is rated power of motor and ʃ is density of air. Weight considered is 4 kg and time of flight is 3 minutes. Selected components based on above mentioned formulae are shown in Table 1.

TABLE 1
SELECTED AVIONICS

Selected components	Rating
Battery	8000 mAh
Motor	650 kV
ESC	40Amps
Flight Controller	APM 2.6

B. Material and Manufacturing Method

ABS and PLA are the most commonly used plastics for 3D printing. They share a few similarities since they are both thermoplastics. ABS is the cheapest plastic of the two filament types and is widely used because it is very durable, strong and flexible. Due to the properties of this material, it can be sanded from jagged edges to smooth curves. Additionally, printed or broken parts can simply be pieced back together with ABS glue. The tensile strength of ABS at yield is 50 MPa and specific gravity is 1.04. High strength to weight ratio is an important parameter for its selection.

C. CAD Model

The quadcopter is modelled using CATIA V5 software. Design constraints are based on size, shape and weight of the avionics as well as spraying system.

1) *Arms:* The arm is independently designed to accommodate 1347 (13*4.7) propellers and EMAX 650KV BLDC motor. Armlength is slightly more than the propeller diameter. Material has been removed from areas with less stress concentration for weight reduction. Fig. 1 shows arm design.

Fig. 1 Arm

2) *Fuselage:*The 2-tier fuselage is designed in such a way that the upper MDF wood plate houses the APM 2.6 flight controllerwith GPS module while the lower ABS plate is designed to accommodate pump and battery. Tank is attached to the lower fuselage plate.

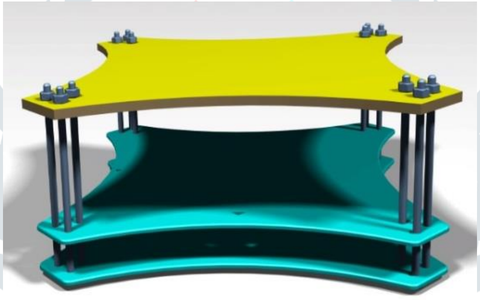
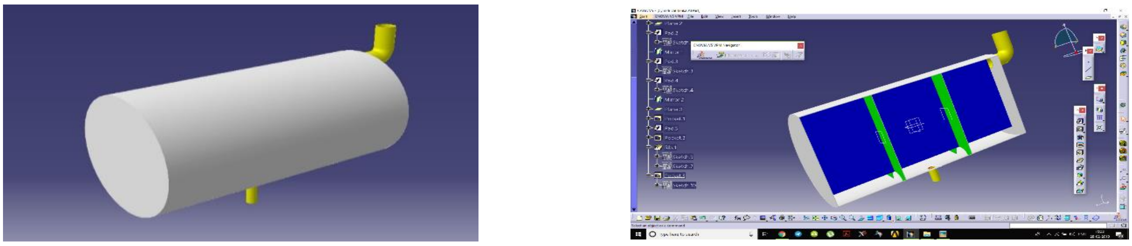


Fig. 2 Fuselage

3) *Landing gear:* It is positioned in such a fashion that maximum support is provided to the arm in static condition meanwhile sufficient ground clearance is maintained from nozzle tip. Fig. 3 shows the landing gear.

Fig. 3 Landing Gear

4) *Tank:* The tank is designed to hold 1.5 litres of fluid. Cylindrical shape is chosen for its high volume to surface area ratio which aids drag reduction. Baffle plates provided within the tank create small compartments which keeps the fluid from sloshing around thus preventing change of CG during flight. Fig. 4 shows 3D view of the tank with positions of filling tube and drain and sectional view of the tank in which the baffles are clearly visible in blue and green.



5) *Frame geometry:*The quadcopter is configured in X shape that characterizes its arms and guarantees stability from the centralized centre of gravity. The X frame also has symmetrical pitch and roll axis which leads to flexibility and predictability in its handling. The isometric view and the diagonaldimension of the frame is shown in Fig.5.

Fig. 4 Isometric and sectional view of tank

III. Analysis

Fig. 5 Diagonal dimension and Isometric view of assembly

Finite element method is used to perform analysis on the frame using ANSYS 18.1 software. Material properties of ABS have been applied to the components.

A. *Static Structural Analysis*

The forces acting on the frame are self-weight of the components like motors, pump, battery and tank, acting downward while the thrust produced by the propellers acts upwards. The components have been analysed individually as well as the assembly at static loading condition is also analysed.The arm is fixed with bolts at the left end. When an upward force of 3kg is applied on the right end, the total deformation observed is 4.34 mm. The equivalent stress induced in arm is 12.74 MPa. At static condition the total deformation of frame assembly after applying all the component masses is 1.6 mm and the equivalent stress is 9.13 MPa.

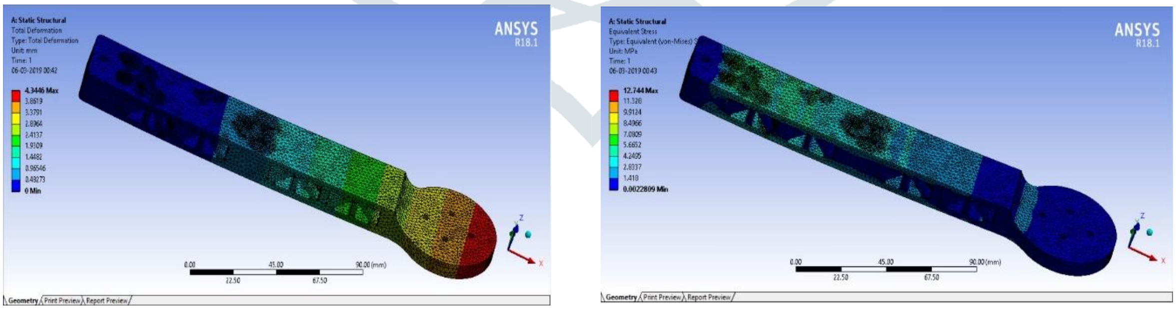


Fig. 6 Total deformation and equivalent stress in arm

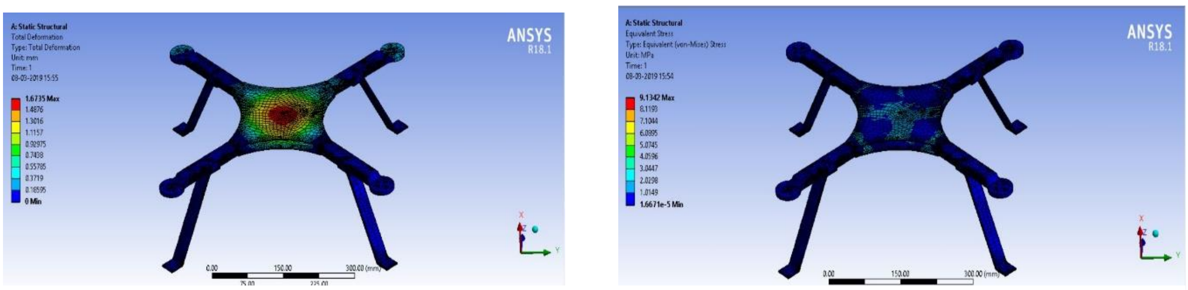


Fig. 7 Total deformation and equivalent stress in frame assembly

B. Modal Analysis

Motors produce vibration during flight. These vibrations are transferred to the frame. The vibrating frequency of EMAX 650KV at 50% throttle is 120.25 Hz. Natural frequency of the quadcopter frame is determined by using modal analysis domain in ANSYS. The fundamental frequency and mode shape of the quadcopter frame is obtained as shown in Fig. 8

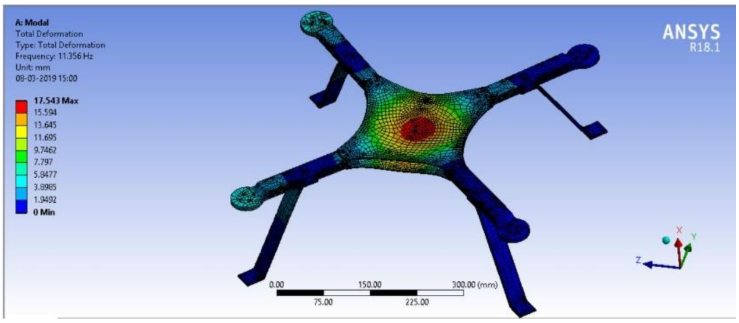


Fig. 8 Resultant amplitude plot at 11.356 Hz

IV. Conclusion

This paper attempts to provide a systematic design approach for a quadcopter with the detailed analysisof each part.Attempt has been made to apply real time boundary conditions. The natural frequency of frame vibration does not coincide with excitation frequency of the motors at operating speed. The frame deformation at static condition is negligible. At static condition the factor of safety for the quadcopter frame is 4.

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