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Design and Development of A Drone Enabled Spraying System for Enhancing Agricultural Productivity- AgriMax 10

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***Abstract*— The AgriMax 10 agriculture drone is mostly designed for crop spraying applications. Prepared with a tank that can hold liquid pesticides or fertilizers, the drone can efficiently spray on the crops from the air, offering several advantages over traditional ground spraying methods. Also, the drone can apply the chemicals more accurately than traditional ground spraying methods. With its advanced sensors and software, the AgriMax 10 can help ensure that the chemicals are applied at the correct rate and in the right areas. This can reduce waste and minimize the risk of over-spraying or under-spraying. Overall, the AgriMax 10 is a useful and powerful tool that can revolutionize the way farmers manage their farms. With its advanced capabilities and features, the drone offers a more efficient, precise and environment friendly alternative to traditional farming methods.**

Keywords— Agriculture, drone, motor, tank, payload

I. Introduction

In the modern agriculture, precision and efficiency are vital to ensuring sustainable and productive crop farming. Traditional methods of fertilizer application, such as manual spraying and ground-based equipment, often fall short in achieving the desired level of precision and uniformity. This is where AgriMax 10, an agricultural drone specifically designed for fertilizer spraying, emerges as a transformative solution. Traditional fertilizer application methods often result in overapplication, increasing production costs and reducing profit margins for farmers. Precision agriculture practices, such as those enabled by AgriMax 10, can optimize fertilizer usage, save farmer's money while improving crop yield. AgriMax 10 is a progressive technology and innovative engineering, meticulously crafted to address the challenges faced by farmers in fertilizer application. Its unique design and advanced capabilities make it an indispensable tool for precision agriculture, allowing farmers to optimize crop health and yield while minimizing environmental impact.

A. Literature review

Zhang Dongyan *et al.* (2015) [1], a backpack sprayer can be fitted with a harness so that the user can wear the sprayer on their back. About 20 liters is the maximum volume of liquid that could fit in the tank. A grasp lever is used to keep pressure constant, making the output of the smoother than the handheld sprayer mechanism's output is the backpack sprayer. A basic, low-cost backpack sprayer that produces little pressure and primarily lacks features such as gauges, assure regulation and a high-pressure pump.
Huang *et al.* (2015) [2], sprayers that run on engines produce more consistent results and cover the spray swath more evenly. Other hand-operated sprayers exist, but they are not widely used in agriculture. Additionally, compared to manual spraying, motorized sprayers offer noticeably more uniform coverage and operate at a constant speed. They can also spray at a higher pressure for improved coverage.
Yallappa D. *et al.* (2017) [3] has published a paper entitled "Quadcopter UAV based Fertilizer and Pesticide Spraying System", in which they give a brief idea about the UAV pesticides sprayer.
S. R. Kurkute *et al.* (2018) [4] in his paper, discussed the use of quadcopters for reconnaissance, as well as demonstrating that small scale UAVs have a broad range of applications, such as safety inspection of construction tools, traffic monitoring, search and rescue operations and temperature and altitude measurements.
Rahul Desale *et al.* (2019) [5] in his paper, concluded that during the Tillering and Flowering stages of rice plants, the same spraying volume was used to compare the effects of different nozzle 14 treatments on droplet deposition and rice planthopper control. There is a significant difference between the droplet density between the nozzles, as shown by the results.
Prof. B. Balaji (2018) [6], the structural, system, propulsion, aerodynamic and integration related problems pertaining to solar-powered aircraft were covered. Furthermore, batteries,

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power management systems, photovoltaic systems, and structural materials make up the technological status of solar aircraft.

Prof. P. Mone (2017) [7], discusses a number of energy extraction and storage techniques, compares their effectiveness to desired features on solar-powered models and provides some guidance on how to choose the best techniques.

II. METHODOLOGY

A. Components

1. Hobbywing X8 Brushless DC Motor

Hobbywing X8 motors are typically brushless, offering higher efficiency, longer lifespan, and better performance compared to brushed motors. Motors like the X8 are often designed to deliver high power and efficiency, making them suitable for various applications, including multirotor drones.

Fig. 1. Motor

2. Propellers

The 3090-propeller made of special high-strength carbon fiber is solid and light, andguarantees great consistency and excellent dynamic balance. This makes it ideal for carrying heavy payloads of fertilizer or other agricultural chemicals.

Fig. 2. Propellers

3. Lithium-Ion battery

Mpower 16800 Li-Ion Battery is a flexible and consistent power source designed for agriculture drones with its high capacity. This battery provides a convenient and safe, with 16800 mAh capacity, extends flight time for enhanced productivity in agricultural applications. With a 6S4P configuration and 11 C discharge rate, this battery offers stable and consistent power output for demanding tasks. AgriMax 10 use two sets of Mpower 16800 batteries in series connection.

Fig. 3. Battery

4. Flight controller

K++ integrates the advantages of the classic flight controller K3A, and strengthens compatibility to form a redundant control system with superior performance, strong reliability and effective guarantee work safety. K++ comes with intelligent vibration analysis function, which can judge the vibration of the aircraft in real time. K++ is equipped with triple redundant IMU and dual barometer sensors.

Fig. 4. Flight controller

5. SIYI MK15 Remote Controller

The SIYI MK15 is a powerful and user-friendly remote controller that is designed for agricultural and industrial drones. It features a 5.5-inch touchscreen display with 1080p resolution, for clear and easy viewing. The remote controller also has a long-range 5.8 GHz communication system that provides up to 15 km of range, making it ideal for controlling drones over long distances.

Fig. 5. Remote controller

6. Tank

This 10 L tank used in AgriMax 10 is made from plastic and is designed specifically for use with agriculture

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pesticides, herbicides, fungicides or nutrients spraying purposes.

Fig. 6. Tank

7. Pump motor

Pump motor is attached below the tank which is used to pump the pesticides out from the tank.

Fig. 7. Pump motor

8. Nozzles

Two Y-type nozzles are used in the AgriMax 10. These nozzles are attached below the motors with the force of the air added to reach the chemicals to the plant without drift. The nozzle tips used in these rods are flat fan models. Both I-type and Y-type of nozzles can be used.

Fig. 8. Nozzles

9. Flow sensor

The flow sensor used in the drone is to fulfill the purpose of indicating the level of water in thetank. Purpose of using this sensor is, during the mission plan it will help us to pause the mission once the water in the tank gets empty. Where it indicates to the pilot to get the tank refilled and continue the spraying.

Fig. 9. Flow sensor

10. Global Positioning System

The GPS module provides precise location information, featuring dual-frequency capabilities (GPS and Beidou) for enhanced accuracy. With a variety of sensitivity modes, the module ensures reliable positioning even under challenging conditions. The compact size and low power consumption make it an ideal choice for drone applications.

Fig. 10. Global Positioning System

11. Power Distribution Board

A Power Distribution Board (PDB) serves as a central hub within an electrical system to manage the distribution of electrical power from a main power source to various subsidiary circuits and devices. Its primary purpose is to ensure safe, efficient, and organized power distribution within a facility or equipment.

Fig. 11. Power Distribution Board

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12. Trans-receiver and antennas

Radio transceivers are devices that combine a transmitter and a receiver into a single unit, thus permitting bidirectional communications. They may be used by UAVs and unmannedvehicles to communicate with each other or with a ground control station (GCS). Control signals, telemetry and payload data such as sensor readings and streaming video may all be transmitted or received by drone radio trans-receiver.

Fig. 12. Trans-receiver and antennas

13. Electronic Speed Controller

The job of the ESC is to switch on power to the motor coils at incredibly fast rates. It works by switching the frequencies of the transistors in the ESC, to throttle the motors. Mostly having three phase power supply, a microcontroller interrupts the input signal, and the built-in program appropriately controls the motor. The correct phase of the current fed to the motor varies with the motor rotation, which must be considered by the ESC.

B. *Working*

The brain of the operation is the flight controller. It receives information from the GPS about the drone's location and uses that data to control the motors via the Electronic Speed Controllers (ESCs). The ESCs adjust the speed of each motor for stable flight. The pilot uses the remote controller to send commands to the transmitter, which then relays those signals to the receiver on the drone. The receiver communicates with the flight controller, allowing the pilot to guide the drone's movement. The battery provides power to the entire system, including the PMU (Power Management Unit), which ensures proper voltage distribution. The payload tank holds the pesticide mixture and a pump pushes the liquid through the nozzles, creating a fine spray that gets applied to the crops as the drone flies along its pre-programmed route.

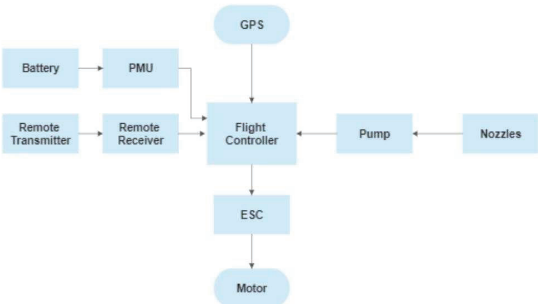

Fig. 13. Block diagram of working process

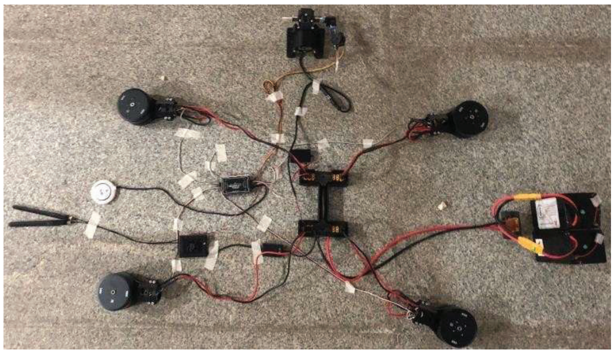

Fig. 14. Connections of the drone

C. *Design*

The CAD model serves as a virtual representation of the physical drone and can be utilized for various purposes. SolidWorks is used for the designing of this drone.

Fig. 15. CAD model of drone

D. *Description of the drone*

Table 1. Description of the drone

Maximum take-off weight	24.4 kg
Dimensions (l*b*h) in mm	2067 * 1612 * 665
Propeller diameter	30 in
Maximum endurance	16 min
Maximum range	0.2 km
Maximum speed	10 m/s
Maximum altitude	30 m
Battery capacity	16800 mAh

E. *Grid generation*

The total mass used in the FEA is derived by regarding the maximum possible mass of the equipment. A 2^{nd} order Quadrilateral and Triangular mesh was applied to Shell Model and Hexahedral and tetrahedral was applied to the Solid model. These types of mesh support plasticity, hyper elasticity, creep, stress stiffening, large deflection and large strain capabilities.

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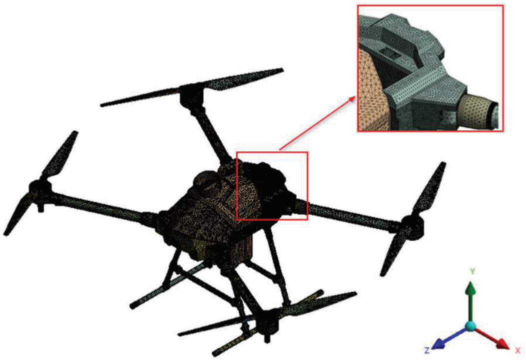

Fig. 16. Mesh of the drone

III. Results and Calculations

A. Loading and boundary conditions

Below are the loading and boundary conditions that we have given to our model. This boundary and loading conditions are based on real life conditions in which the drone will be tested. It can be calculated as follows:

Force acting per arm = (Total MTOW in N / No. of arms) * Factor of Safety

= ((24.4 * 10) / 4) * 1.5

= 91.5 N

But for safety reasons we have considered a force of 95N.

Table 2 Loading and boundary conditions for life of propeller

Loading/ Boundary conditions	Value
Fixed Support	Propeller Hub
RPM	4072

Table 3 Loading and boundary conditions for safety factor, total deformation and equivalent stress

Loading/ Boundary conditions	Value
Fixed Support	Landing gear
Load	95 N acting on the arm rods.

B. Results

Fig. 17. Life of propeller

Fig. 18. Safety factor

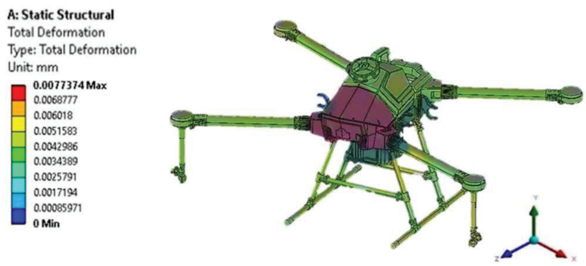

Fig. 19. Total deformation

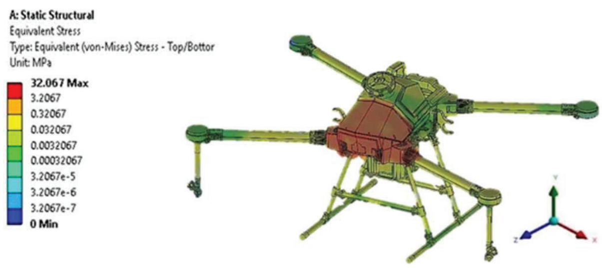

Fig. 20. Equivalent stress

C. Calculations

The overall weight of the drone is calculated by adding the total weight of components and the weight of payload.

Overall weight = Payload + Weight of components

= 10 kg + 14.4 kg

= 24.4 kg

Thrust produced by one propeller with one motor = 9.2536 kg

Total thrust produced = 4 x 9.2536 = 37.0144 kg

Thrust to weight Ratio = Thrust produced / total weight of drone

= 37.01 / 24.4

= 1.51:1

D. Discussions

The drone design has a minimum 2 factor of safety and it is totally safe. As the airframe structure is manufactured using strong materials like aluminum and carbon fiber, the airframe can easily withstand the exerted load forces. As per Static Analysis, maximum deformation is 0.0077 mm and maximum stress is 32 MPa, which is under the limit of maximum loading capacity of the material.

IV. CONCLUSION

This agricultural drone has the ability to revolutionize precision agriculturepractices by introducing a more efficient, precise and environment friendly method of fertilizer application. The drone's autonomous capabilities, will enable farmers to minimize waste, and enhance crop health and productivity. This technology has the potential to significantly improve agricultural yields and reduce environmental impact, contributing to a more sustainable and productive future for farming.

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