Design of a Powder Spraying Device of the Plant Protection Unmanned Aerial Vehicle (UAV)

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Abstract: Powder spraying has unique strength in plant pest prevention and control. This article has first proposed the application of plant protection UAVs for powder spraying, to utilize advantages of powder to improve the control effect. It has designed a plant protection UAV powder spraying device, consisting of the pesticide tank, powder blowing pipe, air pump, fan and controller, put forward the working principle of the powder spraying device using the air pump, fan and rotor to work together to achieve air flow powder transport, pneumatic powder spraying and rotor wind transport. SW software has been employed to complete the structural design and fluid analysis of pesticide powder, indicating the reasonable structural design, proven by the powder spraying and even powder flow. The plant protection UAV powder spraying device manufactured based on this design features a simple structure, convenient operation and high working efficiency. The experimental results in the pest control in the hickory forest show that the pesticide spreads well in the plant canopy and penetrates evenly in all parts of the plant, thus to produce a good control effect. This device has high promotion value in UAV plant protection, especially for fruit tree plant protection.

1. Introduction

Following the pace of agricultural informatization and intelligence in China, unmanned Ariel vehicles (UAVs), especially the multi-rotor plant protection UAVs, have witnessed wider applications in agriculture. UAVs are superior to manned plant protection aircrafts in aspects of vertical takeoff and landing, automatic hovering, flight route planning, one-click takeoff and landing, and easy operation [1]. They feature high operating efficiency, strong penetrability of fog droplets, requiring no special airport for take-off and landing, automatic or autonomous flight, and good maneuverability [2]. They can effectively control outbreaks of pests and diseases in a large area [3]. Compared with round mechanical spraying, spraying by UAVs boasts of higher application efficiency and maneuverability and the rotor wind can effectively prevent the drift of fog droplets, thus producing good prevention and control effect, so that UAVs have been widely used in production [4]. In addition, long-distance control of application of pesticides greatly improves the safety of pesticide spraying and can avoid direct contact between people and harmful substances such as pesticides and thereby reduce personal injuries [5]. It has achieved good practical results in pest control and accordingly has gradually become an important means of pest control [6]. In recent years, there has been a lot of research on UAVs pesticide application devices. Yi GUO studied the UAV precision spraying system based on the wireless sensor network [7]. Dashuai WANG et al. designed a pesticide application control system based on the ARM architecture single chip microcomputer [8].

Yatao WANG et al. designed a multi-rotor plant protection UAV electrostatic spray system [9]. Zhenzhao CEN et al. designed an adaptive variable spraying system for UAVs [10]. Zefeng LIU et al. designed the multi-rotor plant protection UAV variable spraying system [11]. Yanchao ZHANG et al. designed a set of high-precision and highly-controllable UAV spraying simulation platform [12]. Tao CHENG et al. designed a pesticide spraying system for the hickory forest [13].

Search of literatures has discovered that all of the UAV spraying systems have adopted the pressure spraying of the chemical liquids and that no report on the working method of using the UAV for powder spraying or the study of the UAV powder spraying device has been found.

This paper is pioneering in proposing the operation method of using plant protection UAVs for powder spraying, which can achieve good plant protection effect by uniformly spraying the powder. It has developed a plant protection UAV powder spraying device, which is installed in plant protection UAVs and adopts the working principle of air flow powder feeding and the pneumatic powder spraying, to realize uniform powder spraying, high working efficiency, low power consumption, simple structure and convenient operation during the powder spraying.

2. Working Method of Plant Protection UAV Powder Spraying

Pesticides can be applied in a variety of ways, one of which is the powder spraying method. This method is to use the wind force generated by the powder spraying device to blow away the high-efficiency, low-toxicity and low-residue powder pesticides, make the powder particles float in the air, and then settle on the plant surface to control the occurrence and damage of pests and diseases. Compared with the atomizing method, it is easier to use, doesn't require water, and has higher work efficiency [14]. The powder spraying method has higher efficiency because the powder particles have a unique movement behavior in the air, namely Brownian motion and flying motion, both making tiny particles suspended in the air for a long time without sinking quickly, especially in the case of wind and air flow disturbances, when the suspension and drift of these particles in the air are longer and will spread in a longer distance with the movement of the airflow [15]. It can be seen that spraying powder has unique advantages for preventing plant diseases and insect pests. Using plant protection UAVs to spray powder pesticides can make the pesticides better spread and penetrate in the plant canopy, so that the precipitation is evenly distributed in various parts of the plant, thus to achieve very high efficacy, especially in the prevention and control of pests in fruit trees.

Although the powder spraying technology has obvious advantages, no report on its application in plant protection UAV has been found. This paper proposes the application of plant protection UAVs for powder spraying, to utilize the advantages of powder and thereby to improve the control effect. It is a new technology applied by plant protection UAVs, has turned over a new leaf on plant protection UAV research, and thus has high theoretical value.

3. Main Structure and Working Principle of the Powder Spraying Device

The plant protection UAV powder spraying device is composed of the pesticide tank, powder blowing pipe, air pump, fan, and controller. The pesticide tank is used for holding the pesticide powder. The powder blowing pipe is used to send compressed air into the powder tank to make the powder rise, so as to realize air flow powder transfer. The air pump is used to generate high-speed airflow, which is blown into the pesticide tank through the powder blowing pipe. The fan is designed for generating air flow, enabling the medicine powder to flow along the powder transport pipe, and spray the pesticide powder.

The plant protection UAV powder spraying device works like this: first add pesticide powder, which is no higher than 1/2 of the pesticide tank, from the pesticide feeding mouth to the pesticide tank and then covers the powder feeding mouth tightly. Then control the plant protection UAV to arrive at the designated location, open the air pump and fan through the controller, when the air pump generates high-speed airflow that enters the powder blowing pipe and then blows into the pesticide tank from its outlet, so that the pesticide powder rises under the action of the airflow, and the fan operates to generate negative pressure in the powder transport pipe, enabling the pesticide powder to be transported to the fan along the transport pipe and ejected under the action of the fan. Finally, transport the pesticide powder to the plant canopy under the action of the UAV rotor downwind. Its working principle is shown in Figure 1.

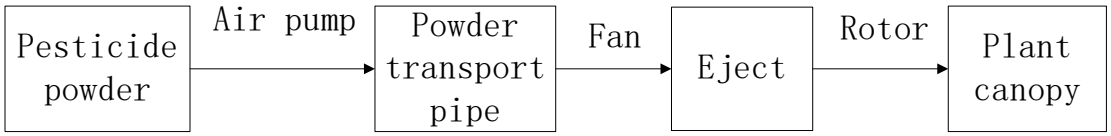

Figure 1. Working Principle of the Powder Spraying Device

4. Structure Design of the Powder Spraying Device

4.1 Design of the Pesticide Tank

The pesticide tank consists of the tank body, powder transport pipe, powder feeding mouth, powder feeding mouth cover and lower cover (Figure 2). The tank body is a circular truncated cone-shaped structure, with the diameter of the upper part larger than that of the lower part. This structure is conducive to the diffusion of pesticide powder. The upper part of the tank body has four outlets, which are connected to the powder transport pipe. The powder transport pipe is an elbow with a circular cross-section, with one end connected to the pesticide tank and the other being the outlet. At the outlet of the powder transport is a fan mounting hole. The top side of the tank body has a powder feeding mouth screwed with a cover. The pesticide powder can be added into the tank body after the powder feed mouth cover is opened. The top of the pesticide tank is designed with 3 studs, used to connect the powder tank to the bottom plate of the UAV. The bottom of the tank body is an external thread structure used to install the lower cover. The lower cover is connected with the tank body by internal threads, with a through hole in the center for installing the powder blowing pipe, and a bracket outside for installing the powder blowing pipe.

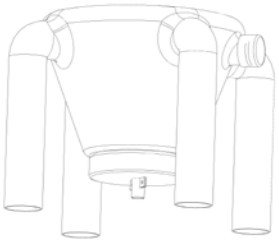

Figure 2. Pesticide Tank

4.2 Design of the Powder Blowing Pipe

The powder blowing pipe is composed of the cavity and straight pipe (Figure 3). The cavity is located at the upper part of the powder blowing pipe and has evenly distributed through holes (namely the blowing holes) on its lower surface, to blow compressed air to the pesticide tank. Since the powder blowing pipe is installed at the bottom of the pesticide tank, in order to prevent the pesticide powder from entering the powder blowing pipe, the top of the powder blowing pipe is designed as a closed structure. The lower part of the powder blowing pipe is a straight pipe, used to install the air pump and deliver the air flow of the air pump to the cavity. The side wall of the straight pipe has a mounting bracket, connected with the bracket of the pesticide tank lower cover by bolts.

4.3 Selection of the Air Pump

The air pump is used to generate high-speed airflow to make the pesticide powder in the pesticide tank rise. To reduce the weight of the powder spraying device and make it portable for UAVs, the miniature air pump has been selected, with rated voltage: DC12V, pressure:> 525 mmHg

(+ 70KPa), and flow rate:> 13.0 L / Min.

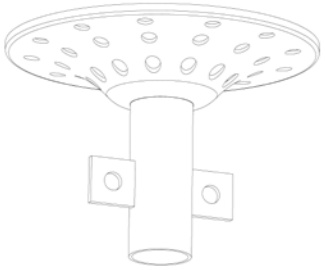

Figure 3. Powder Blowing Pipe

4.4 Selection of the Fan

The fan is used to generate airflow so that the pesticide powder flows along the powder transport pipe under the action of the airflow and is ejected from the fan. This design has applied an axial fan, with rated voltage: DC12V, speed 600RPM, and air volume 66CFM. The fan is installed at the outlet of the transport pipe through bolts.

4.5 Design of the Controller

The controller is used to control the work of the air pump and the fan, open and close them, and adjust the speed of the fan, thereby to regulate the powder spraying amount.

4.6 Design of the Powder Spraying Device

After the design of all parts is completed, SW software is used for assembling (Figure 4), and checking the interference between the parts. After no interference is found, SWFL is used to perform fluid analysis on the dynamic flow of pesticide powder, with results shown in Figure 5, which shows that powder spraying can be achieved in an even manner. The application of the Powder Spraying Device on the plant protection UAVs is shown in Figure 6.

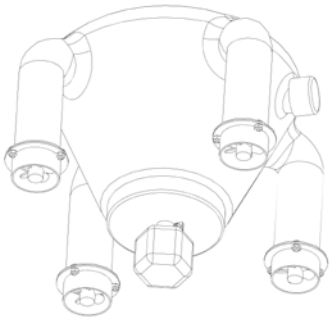

Figure 4. Plant Protection UAV Powder Spraying Device

Conclusions

This article has first proposed the application of plant protection UAV for powder spraying, to utilize advantages of powder to improve the control effect. It has designed a plant protection UAV powder spraying device, consisting of the pesticide tank, powder blowing pipe, air pump, fan and controller, put forward the working principle of the powder spraying device using the air pump, fan and rotor to work together to achieve air flow powder transport, pneumatic powder spraying and rotor wind transport. SW software has been employed to complete the structural design and fluid analysis of pesticide powder, indicating the reasonable structural design, proven by the powder spraying and even powder flow. The plant protection UAV powder spraying device manufactured

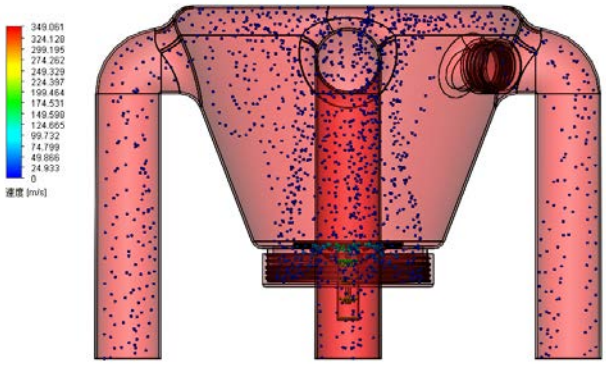

Figure 5. Dynamic Flow of the Pesticide Powder

Figure 6. The Application of the Powder Spraying Device on the Plant Protection UAVs

based on this design features a simple structure, convenient operation and high working efficiency. The experimental results in the pest control in the hickory forest show that the pesticide spreads well in the plant canopy and penetrates evenly in all parts of the plant, thus to produce a good control effect. This device has high promotion value in UAV plant protection, especially for fruit tree plant protection.

Acknowledgements

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