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

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Abstract: The smoke generator used in the field of plant protection features a small particle size of the sprayed smoke, which can be diffused with the airflow and has excellent penetration and adhesion. Its dosage is small, so is the pollution. It is safe, labor-saving and highly efficient. This paper has first proposed the use of plant protection UAVs for smoke spraying, a new technology that has turned over a new leaf over plant protection UAV research and can provide theoretical basis for related research. A plant protection UAV smoke spraying device has been developed, consisting of the smoke tank, combustion chamber, fan, igniter, and controller. It utilizes pesticide burning to generate smoke, and sprays it to the plant canopy under the action of the fan and rotor airflow. It features a simple structure, safe and reliable operation, low energy consumption, high working efficiency and easy operation, thus presenting a broad application prospect. SolidWorks software is applied for structural design and smoke fluid analysis, concluding that the structural design is reasonable and the smoke flows evenly in the smoke tank and can generates even smoke. The plant protection UAV smoke spraying device manufactured based on this design has been proven in the experiments on disease and pest control in hickory forest to have good diffusion and penetrability in the plant canopy and to be evenly distributed on all parts of the pant, thus generating a good prevention and control effect.

1. Introduction

The plant protection machinery is an inevitable product of agricultural development and is well known for its effective control of diseases and insect pests. It is an indispensable and important part of agricultural development since modern agriculture is strongly dependent on such plant protection machinery, and thus has become an important driver for agricultural modernization [1]. Plant protection UAV is an unmanned aircraft used for agricultural and forestry plant protection, mainly using ground remote control or GPS flight control to achieve spraying [2]. With the development of agricultural informatization and intelligence in China, agricultural production pays more and more attention to the operation quality of plant protection UAV [3]. Compared with the manual operation or traditional plant protection machinery, the plant protection UAV has the following advantages in the prevention and control of crop diseases and insect pests: First, it has high operating efficiency, capable of preventing and controlling outbreak of large-scale diseases and insect pests in a timely manner. Second, it has obvious effect on water and pesticide, to cause a low cost of prevention and control and small resource consumption. Third, it has strong adaptability, able to carry out spraying tasks on various terrains. Fourth, through applying remote control high-altitude operation, it can avoid the harm of the pesticide to the workers, thus being safer and more reliable [4] [5]. Owing to the abovementioned advantages, it has developed rapidly in China in recent years and aroused wide attention on its development prospect [6] [7]. Many scholars have carried out research related to plant protection UAV, and also produced numerous research findings. Liqing CHEN et al. designed and tested the unmanned spraying electronic control system [8]. Haiyan ZHANG et al. conducted research on the plant protection UAV pesticide spraying operation effect on the rice field [9]. Chao ZHU et al. designed a highly efficient adaptive spraying plant protection UAV [10]. Daoqi LIU et al.

conducted the spraying evenness test on a multi-rotor plant protection UAV [11]. Jiajie LU et al. performed a study on the spraying performance of agricultural aviation electrostatic spraying system [12].

This paper has first proposed the use of plant protection UAVs for smoke spraying, a new technology that has turned over a new leaf over plant protection UAV research and can provide theoretical basis for related research. A plant protection UAV smoke spraying device has been developed, consisting of the smoke tank, combustion chamber, fan, igniter, and controller. It utilizes pesticide burning to generate smoke, and sprays it to the plant canopy under the action of the fan and rotor airflow. It features a simple structure, safe and reliable operation, low energy consumption, high working efficiency and easy operation, thus presenting a broad application prospect.

2. Plant Protection UAV Smoke Spraying Technology

The poisonous smoke technology is a ground pest control technology with high work efficiency, low cost, low pollution and good control effect. At present, it is mainly adopted in portable pulse smoke generators and greenhouse normal temperature smoke generators. The smoke produced by the smoke generator can be spread evenly. It produces a small smoke particle size that can diffuse with the airflow, and thus feature excellent penetration and adhesion performance. It requires a small dosage, to produce less pesticide residue and less pollution. It is also safe, labor-saving and efficient [13]. In the 1980s, China introduced the room temperature smoke technology and improved the atomization performance of the room temperature smoke generator developed based on this technology through reducing the contact time of workers and pesticides, and lowering the poisoning of personnel to some degree [14]. The smoke spraying technology can solve the difficulties caused by factors such as forest height, forest density, and lack of water resources. Compared with powder spraying, it is more labor-saving and reduces the labor intensity. It can save the cost of prevention and control, and also ensure effect of pesticides applied after rainfall [15]. Although the smoke 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 smoke spraying, a new technology applied by plant protection UAVs that has turned over a new leaf on plant protection UAV research and thus has high theoretical value.

3. Main Structure and Working Principle

The plant protection UAV smoke spraying device is composed of the smoke tank, combustion chamber, fan, igniter, and controller. The smoke tank is used for containing smoke, the combustion chamber for burning pesticides, fan for ejecting smoke, the igniter for generating electric sparks and igniting the pesticides in the combustion chamber, and the controller for opening and closing the igniter and fan.

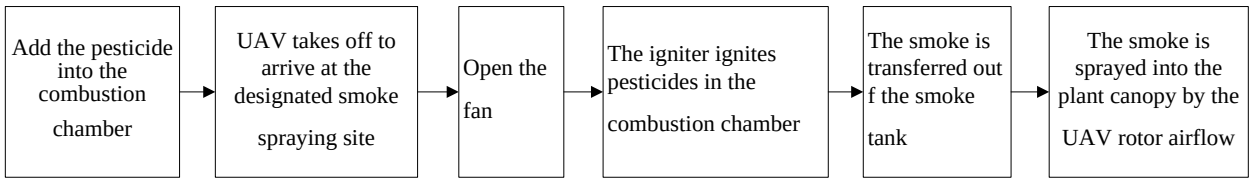

Figure 1. Working Principle of the Plant Protection UAV Smoke Spraying Device

It burns pesticides to generate smoke and spray it to the plant canopy under the action of fan and rotor airflow. It works like this: first, put the pesticide into the combustion chamber, then install the combustion chamber in the corresponding position of the smoke tank, insert the electrode of the igniter into the bottom of the combustion chamber. After that, the UAV takes off to the designated smoke spraying site, and the igniter and fan are opened by the controller. The electrode of the igniter generates an electric spark to ignite the drug in the combustion chamber, so that the pesticide burns. The igniter is remotely controlled by the controller. The burning pesticide generates smoke and diffuses in the smoke tank, to generate a negative pressure inside and transfer out the smoke.

The fan can be adjusted by the controller to generate different amounts of smoke. The output smoke is sprayed to the canopy of the plant under the action of the UAV rotor airflow. Its working principle is shown in Figure 1.

4. Design of the Smoke Spraying Device

4.1 Design of the Smoke Tank

The smoke tank (Figure 2) is composed of the tank body, door, spring seat, spring, upper combustion chamber mounting base, lower combustion chamber mounting base and baseplate. The tank body is a hollow cylindrical structure with protruding shoulders at the top and the bottom. The top of the tank body is sealed. There are three through holes on the top shoulder for bolting the tank body to the UAV baseplate and four through holes on the side of the tank body upper side to be used to input air into the smoke tank to ensure that there is enough air supply for the fuel's burning smoothly. On the side of the tank body is an opening with a push-pull door for putting in and taking out the combustion chamber. There is a spring seat on the top inside of the tank body for installing the spring. The upper combustion chamber mounting base is connected with the spring to fix the upper of combustion chamber. The lower combustion chamber mounting base is connected to the baseplate for fixing the bottom of the combustion chamber. The bottom of the tank body is an opening with a baseplate used to install the lower combustion chamber mounting base. There are 3 through holes on the shoulder of the tank body bottom to install the fan.

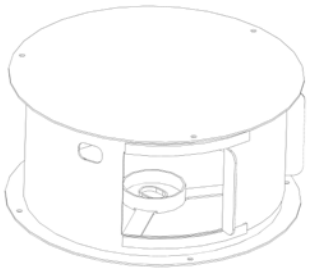

Figure 2. Smoke tank

4.2 Design of the Combustion Chamber

The combustion chamber (Figure 2) is cylindrical, with a cavity inside and an opening at the top. There is a lid on the top. Open the lid to add pesticide smoke to the combustion chamber. Through holes are uniformly distributed on the side wall of the combustion chamber to release smoke. There is a through hole at its bottom for inserting the igniter electrode. When using the device, open the lid and put the medicine into the combustion chamber, then close the lid, open the smoke tank door, and compress the spring in the upper chamber. After the spring is compressed, put the combustion chamber between the upper combustion chamber mounting base and the lower combustion chamber mounting base, and then release the spring. Under the spring elasticity, the combustion chamber is fixed in the upper combustion chamber mounting base and the lower combustion chamber mounting base. The igniter is inserted into the combustion chamber from the hole at the bottom of the combustion chamber.

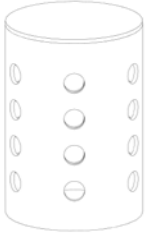

Figure 3. Combustion chamber

4.3 Selection of the Igniter

The igniter sleeted is a pulse igniter, with the input voltage 1.5V and powered by the UAV power supply. The pulse igniter is a pulsed high-frequency oscillator composed of electronic components. The high-frequency voltage generated by the oscillator is raised to a high voltage of 15KV by a step-up transformer, and discharges at the tip of the electrode, to generate sparks to burn pesticides in the combustion chamber.

4.4 Selection of the Fan

The fan is an axial fan that can be adjusted by PWM. During operation, the fan can be adjusted by the controller to achieve different smoke spraying amounts and meet the needs of different application dosages. The fan is connected to the lower shoulder of the smoke tank by bolts, is installed at the bottom of the smoke tank, and is powered by the UAV power supply. When working, the fan generates air flow to produce negative pressure inside the smoke tank and thus output smoke. In order to meet the needs of different smoke injection amounts, the fan speed can be adjusted through the controller to achieve different smoke injection amounts.

4.5 Simulation Analysis

After the above parts are designed, SolidWorks software is used for assembly (Figure 4) and checking the interference between the parts. No interference means reasonable structure design. Then SolidWorks FloXpress is used to make fluid analysis on smoke, with results showing that smoke flows evenly in the smoke tank and is sprayed in an evenly manner. The application of the smoke spraying device on the plant protection UAVs is shown in Figure 5.

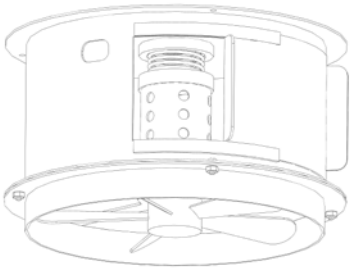

Figure 4. Plant protection UAV smoke spraying device

Figure 5. The application of the smoke spraying device on the plant protection UAVs

Conclusions

This paper has first proposed the use of plant protection UAVs for smoke spraying, a new technology that has turned over a new leaf over plant protection UAV research and can provide theoretical basis for related research. A plant protection UAV smoke spraying device has been

developed, consisting of the smoke tank, combustion chamber, fan, igniter, and controller. It utilizes pesticide burning to generate smoke, and sprays it to the plant canopy under the action of the fan and rotor airflow. It features a simple structure, safe and reliable operation, low energy consumption, high working efficiency and easy operation, thus presenting a broad application prospect. SolidWorks software is applied for structural design and smoke fluid analysis, concluding that the structural design is reasonable and the smoke flows evenly in the smoke tank and can generate even smoke. The plant protection UAV smoke spraying device manufactured based on this design has been proven in the experiments on disease and pest control in the hickory forest to have good diffusion and penetrability in the plant canopy and to be evenly distributed on all parts of the pant, thus generating a good prevention and control effect.

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