Design of a Plant Protection Unmanned Aerial Vehicle Centrifugal Atomizing System

Yi Guo[1, a, *] and Xiaoyun Wu[1, b]

[1] Department of Horticulture Beijing Vocational College of Agriculture, Beijing, 102442, China

[a] email: guoyibvca@163.com, [b] email: 943387022@qq.com

[*] corresponding author

Keywords: Unmanned Aerial Vehicle (UAV); Atomizing system; Centrifugal; Plant Protection

Abstract: A centrifugal atomizing system has been designed for plant protection unmanned aerial vehicles (UAVs) with the centrifugal atomizing principle with the aim to ensure good prevention and treatment effect of the plant protection UAV and reduce power consumption. It consists of a pesticide tank, an electromagnetic valve, a dispenser, a pesticide transport pipe, an atomizer and a mounting track. SolidWorks is used for virtual design and simulation analysis to produce a 3D model and performs finite element analysis on the mounting rack to optimize the structure, verify motion reliability of the atomizer and the atomizing effect. The prototype test results show that the system can complete atomization of the pesticide liquid without pressurization, which not only achieves a good atomization effect, but also saves electricity. This system features a simple structure, low manufacturing cost, safe and reliable use, easy maintenance, and low failure rate and thus boasts of broad promotion value in UAV plant protection.

1. Introduction

Control of agricultural diseases and insect pests is a key element of agricultural production and a major plant protection method to ensure smooth growth and increase yield of crops. Currently, spraying chemical pesticides is the main plant protection method. [1] For a long time in China, pesticide spraying mainly adopts ground plant protection, mostly the traditional high-volume and large-droplet spraying technology. This has low efficiency and is easy to cause serious environmental pollution and fall in quality of agricultural products due to excessive application of pesticides, which accordingly is unable to meet the needs of sustainable agricultural development. [2] In order to rapidly and efficiently control plant diseases and insect pests, it is urgent to use a more advanced and scientific application technology to replace the traditional plant protection operation method. In the field of plant protection, it is inevitable for promoting stable agricultural production through accelerating the mechanization level of pesticide application equipment, improving the application technology, and strengthening the ability to control pests and diseases. [3] The agricultural plant protection UAV has applied a UAV equipped with a spraying device and been installed with a control system and sensor for control, thereby to accurately spray pesticides over crops at the certain amount. It has overcome problems of low efficiency of manual work and inaccessible places by the ground spraying machinery. In recent years, the rapid development and application of plant protection UAV has been highly valued by the field of agricultural plant protection. [4,5] In order to promote sustainable development of agricultural practices, China vigorously supports the development of agricultural UAVs. [6]

Compared with traditional pesticide application methods, agricultural UAV plant protection operations have obvious features and advantages such as low operating cost, high efficiency, less environmental pollution, small size, and high accuracy. [7,8] The agricultural UAV can perform takeoff and landing, refueling, and filling of medicinal fluids in the field, rather than a special airport,

during plant protection operations, which thus reduces flight time and fuel consumption, and guarantees efficiency. Accordingly, it has higher application efficiency and maneuverability than ground mechanical spray. [9] The UAV can well adapt to complex terrains such as hills, mountains and slopes and is suitable for agricultural pest control owing to its low-speed operation conditions and the downward airflow produced by its rotor wings. It has demonstrated obvious characteristics and advantages in practical application. [10, 11] Therefore, it will be a better choice to apply the UAV spray technology and equipment for crop pest control. The application of UAV technology in agriculture and other fields is undoubtedly a great change in agricultural modernization. With gradual gathering of land to large grain growers and family farmers, plant protection UAVs will surely play an important role in future agricultural application. [12]

To ensure good protection effect of the plant protection UAV for plant protection, an atomizing system with excellent performance will be required. At the same time, considering the limited number of batteries carried by the plant protection UAV, the atomizing system is required to save energy as much as possible. In this paper, a centrifugal atomizing system for the plant protection UAV has been designed. It uses the centrifugal atomization principle to atomize the pesticide liquid without pressurization, which not only produces a good atomization effect, but also saves electricity. This system feature a simple structure, low manufacturing cost, safe and reliable use, easy maintenance, and low failure rate and consequently will have broad promotion value in UAV plant protection.

2. Overall Structure and Working Process

The plant protection UAV centrifugal atomizing system is mainly composed of a pesticide tank, an electromagnetic valve, a dispenser, a pesticide transport pipe, an atomizer and a mounting rack. The pesticide tank is designed for holding the chemical solution and fixing the entire atomizing system with the UAV's rack, the electromagnetic valve for controlling the liquid in the pesticide tank to flow into the dispenser, the dispenser for distributing the pesticide liquid to each pesticide transport pipe , the pesticide transport pipe for transporting the liquid to each atomizer, the atomizer for atomizing the liquid and the mounting rack is designed for fixing the atomizer and the UAV rack.

The system works like this: pesticide liquid is first added to the pesticide tank and then the UAV takes off and lands at the place where pesticide application is needed. The electromagnetic valve will be opened under the control of the remote controller, so that the pesticide liquid in the pesticide tank flows into the dispenser under gravity, where the liquid will be distributed to the pesticide transport pipe s. After entering the pesticide transport pipe , the liquid will flow to the dropper box of the atomizer, where the liquid droplets will be thrown to the center of the rotating disk, where the liquid gains a centrifugal force as a result of rotation of the rotating risk and will be thrown out from the gap between the upper and the lower rotating disks. At the same time, the liquid is further atomized under the downwash airflow generated by the rotation of the wings to apply on the plants. After completion of the application, the electromagnetic valve is closed by the remote controller and the UAV returns. The working process is shown in Fig. 1.

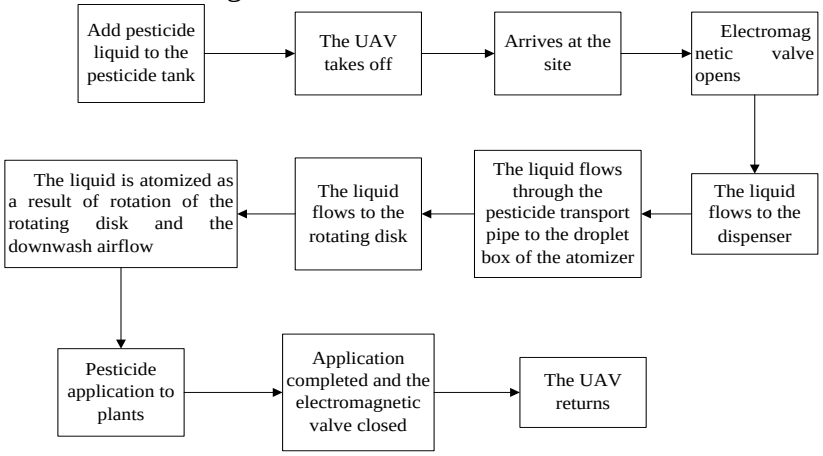

Figure 1. Working process

3. Design of the Spare Parts

3.1 Design of the Pesticide Tank

The pesticide tank (Fig. 2) is flat cylindrical and made of engineering plastics, consisted of a tank body, a pesticide tank cover and a pesticide outlet. The tank body holds the pesticide liquid and its upper has two mounting holes for fixing the pesticide tank and the UAV rack. The upper part of the tank body is a feeding port that is equipped with a pesticide tank cover. On the pesticide tank cover is an air vent that maintains the pressure of the pesticide liquid in the pesticide tank to be the atmospheric pressure and avoids negative pressure due to outflow of the pesticide liquid. At the bottom of the pesticide tank body is the pesticide outlet, which is equipped with the electromagnetic valve.

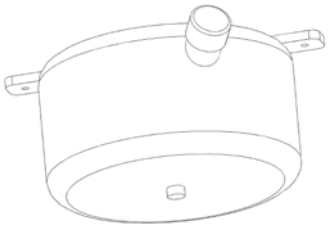

Figure 2. Pesticide tank

3.2 Selection of the Electromagnetic Valve

The electromagnetic valve adopts DC12V and is powered by batteries of the UAV. It is opened and closed by the remote controller. The inlet and outlet of the electromagnetic valve is DN 20mm, with the water inlet connected to the outlet of the pesticide tank, and the outlet connected to the dispenser.

3.3 Design of the Dispenser

The dispenser (Fig. 3) is consisted of housing and a pesticide transport pipe. The housing is a hexagonal box-like structure, with six sides having the pesticide outlets. The pesticide outlets are used to install the pesticide transport pipe. The bottom of the housing is closed and the upper part of the housing has mounting holes for connecting with the water outlet of the electromagnetic valve. The pesticide transport pipe is a PE pipe with an inner diameter of 12mm. One end of the pesticide transport pipe is connected to the pesticide outlet of the dispenser and the other end to the pesticide inlet of the dropper box. The connections are fixed by clamps to ensure sealing.

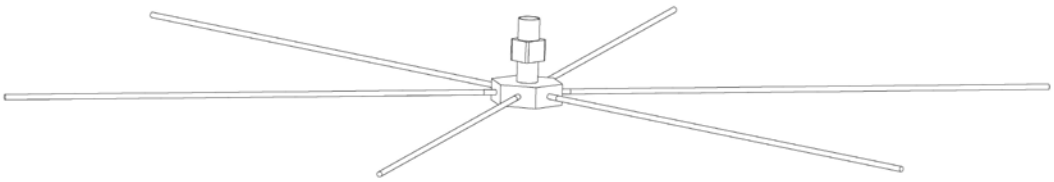

Figure 3. Dispenser

3.4 Design of the Mounting Rack

The mounting rack (Fig. 4) is made of stainless steel and has mounting holes at the top to connect the UAV's rack by bolts. It has mounting holes at the bottom for attaching to the atomizer with bolts.

3.5 Design of the Atomizer

The atomizer (Fig. 5), the core component of the atomizing system, consists of a motor, dropper box, dropper box cover, rotating disk, bolts, sleeves and nuts. The motor is an AC brushless high-speed motor, which is powered by UAV power supply. The motor drives the rotating disk to rotate, so that the pesticide liquid could drop into the rotating disk and obtain centrifugal force to be thrown out from the rotating disk. The inside of the dropper box is a cavity, and on its side walls are mounting holes and a pesticide inlet. The cover is placed above the dropper box and thus forms a closed structure with the dropper box to prevent the liquid from flowing out of the upper part. At the bottom of the dropper box are six pesticide outlets, which are used to disperse and drip the liquid into the rotating disk, which is conducive to atomization. The dropper box and the motor are connected by bolts and sleeves. The rotating disk is a tapered a double-layer structure. Its upper and lower layers are supported by six partitions to assist with atomization of the pesticide liquid. In the middle of the rotating disk is the mounting hole, which is connected to the shaft of the motor through the pins and nuts on the motor shaft, so that the rotating disk is driven to rotate when the motor shaft rotates.

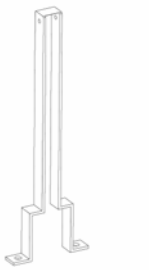

Figure 4. Mounting rack

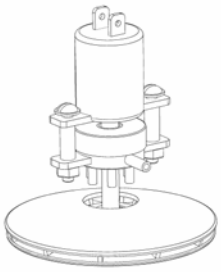

Figure 5. Atomizer

4. Simulation Analysis

After completion of design of the parts, the assembly function of the SolidWorks is used to virtually assemble the parts to form a 3D model (Fig. 6). SolidWorks interference checking function is utilized to ensure no interference between parts. Using the finite element analysis function provided by SolidWorks, the finite element analysis of the mounting rack is performed to optimize the structure. The kinematic analysis function of SolidWorks is used to verify motion ability. Then its fluid analysis function is applied to verify the effect of atomizing. The verification shows that there is no interference between the parts, featuring reliable movement, and the pesticide liquid can be well atomized. The installation effect of the centrifugal atomizing system installed on the plant protection UAV is shown in Fig. 7.

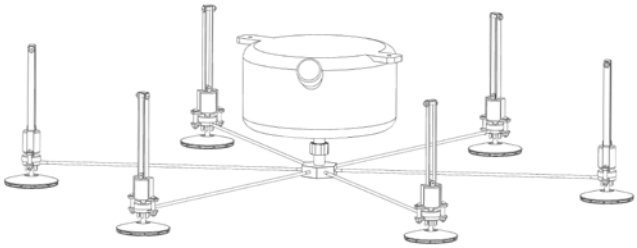

Figure 6. Centrifugal atomizing system

Figure 7. Installation effect

Conclusion

A centrifugal atomizing system has been designed for plant protection UAVs with the aim to ensure good prevention and treatment effect of the plant protection UAV and reduce power consumption. It consists of a pesticide tank, an electromagnetic valve, a dispenser, a pesticide transport pipe, an atomizer and a mounting track.

SolidWorks is used for virtual design to form a 3D model. SolidWorks interference checking function is utilized to ensure no interference between parts. Using the finite element analysis function provided by SolidWorks, the finite element analysis of the mounting rack is performed to optimize the structure. The kinematic analysis function of SolidWorks is used to verify motion ability of the atomizer. Then its fluid analysis function is applied to verify the effect of atomizing.

The prototype test results show that the system can complete atomization of the pesticide liquid without pressurization, which not only achieves a good atomization effect, but also saves electricity. This system features a simple structure, low manufacturing cost, safe and reliable use, easy maintenance, and low failure rate and thus boasts of broad promotion value in UAV plant protection.

Acknowledgements

This research is funded by Research on and Demonstration of the UAV Plant Protection Technology in Mountainous Areas under the Technical Assistance/Technology Promotion Project of Beijing Vocational College of Agriculture (Project No.: XY-KB-19-01).

References

[1] Song Leijie, Li Jianping, Yang Xin, Wang Pengfei, Liu Hongjie, Research Progress on Pesticide Application Technology for Plant Protection Drone[J]. Modern Agricultural Science and Technology, 2019, (11): 125-128.

[2] Liu Wulan, Zhou Zhiyan, Chen Shengde, Luo Xiwen, Lan Yubin, Status of Aerial Electrostatic Spraying Technology and its Application in Plant Protection UAV[J]. Journal of Agricultural Mechanization Research, 2018, 40(05): 1-9.

[3] Lou Shangyi, Xue Xinyu, Gu Wei, Cui Longfei, Zhou Qingqing, Wang Xin, Current Status and Trends of Agricultural Plant Protection Unmanned Aerial Vehicle[J]. Journal of Agricultural Mechanization Research, 2017, 39(12): 1-6+31.

[4 Bae Y, Koo Y M, Flight attitudes and spray patterns of a rollbalanced agricultural unmanned helicopter[J]. Applied Engineering in Agriculture, 2013, 29 (5): 675-682.

[5] Zhu H, Lan Y B, Wu W F, et al, Development of a PWM precision spraying controller for unmanned aerial vehicles[J]. Journal of Bionic Engineering, 2010, 7 (3): 276-283.

[6] Liu Zefeng, Tang Yu, Luo Shaoming, Hou Chaojun, Huang Weifeng, Chen Yayong, Design of a Variable Spraying System Based on Multi-rotor Unmanned Aerial Vehicle[J]. Journal of Agricultural Mechanization Research, 2018, 40(12): 47-54.

[7] Duan Liti, Liu Yangyang, Ru Yu, Research development and prospect of plant protection UAV aerial application monitoring technology[J]. Journal of Chinese Agricultural Mechanization, 2018, 39(06): 108-113.

[8] Zhang Dongyan, Lan Yubin, Chen Liping, Wang Xiu, Liang Dong, Current Status and Future Trends of Agricultural Aerial Spraying Technology in China[J]. Transactions of the Chinese Society for Agricultural Machinery, 2014, 45(10): 53-59.

[9] Cai Yanlun, Qiu Baijing, Shen Wei, Research on Low Altitude Electrostatic Spray of UAV[J]. Journal of Agricultural Mechanization Research, 2018, 40(08): 188-192.

[10] Lan Yubin, Wang Linlin, Zhang Yali, Application and prospect on obstacle avoidance technology for agricultural UAV[J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2018, 34(9):104-113.

[11] Ru Yu, Jin Lan, Jia Zhicheng, et al, Design and experiment on electrostatic spraying system for unmanned aerial vehicle[J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2015, 31(8): 42-47.

[12] Xu Xiaojie, Chen Shengde, Zhou Zhiyan, Lan Yubin, Luo Xiwen, Analysis and Thinking of Evaluation Methods About the Main Performance Indexes of Plant Protection UAV[J]. Journal of Agricultural Mechanization Research, 2018, 40(12): 1-10.