PAPER • OPEN ACCESS

Research of flow and deposition characteristics in spraying process of large load plant protection unmanned helicopter

View the article online for updates and enhancements.

Research of flow and deposition characteristics in spraying process of large load plant protection unmanned helicopter

Yang Yafei[*]**, Wang Guoqiang, Jin Zhuo, Tao Deqing, Li Xiao, Wang Shuaihua**

(Jiangsu Agri-animal Husbandry vocational college, Taizhou, 225300, China)

*Corresponding author's e-mail: yangyafei890506@163.com

Abstract. As a new technology in the field of agricultural plant protection, spraying by unmanned helicopter with large load has the advantages of high spraying efficiency, wide application range, low operation cost and less environmental pollution. The characteristics of flow and deposition in spraying process of uavs with large load were studied, which can provide theoretical basis for optimizing spraying parameters of uavs, and further improve spraying quality of uavs.

1. Introduction

China is a big agricultural country. As the primary industry, agriculture is the foundation of people's livelihood and a strong guarantee for the country. The protection of food security is a basic national policy of our country. According to statistics, China's annual pest control is not timely caused by food losses of more than 10%; China has a vast territory, with hills and mountainous areas accounting for 61% of the total land area, with a total cultivated area of 121715.9 thousand hectares. At present, China's agricultural production efficiency is relatively low, the agricultural plant protection mechanization, automation, and precision degree are low, and the plant protection machinery spraying efficiency is low. In China, manual plant protection machinery and tools account for 92% of the total social population, small and medium-sized mechanical plant protection machinery accounts for about 6%, and tractor plant protection machinery accounts for about 1%. Meanwhile, manual plant protection machinery and tools are responsible for more than 78% of the total area of crop pest control. The diversification of meteorological conditions and regional location leads to the huge difference in agricultural operation scale and cultivation mode, which makes it difficult to achieve full mechanization and automation of plant protection operations. At the same time, China's per capita arable land area is relatively small, farmland is relatively dispersed, in the middle and late stage of crop growth, plant canopy is relatively dense, making it difficult for ground machinery to enter farmland for plant protection operations; It is difficult and ineffective to use common ground machinery in mountainous and hilly areas.

2. research status at home and abroad

Domestic scholars mainly focus on the field of small single-rotor and multi-rotor plant protection uav, while foreign scholars mainly focus on the development and improvement of the flight model of fixed-wing aircraft, or only in a more ideal situation for the preliminary exploration of aerohead atomization characteristics. The interaction between droplet deposition and downwash flow and the mechanism of droplet migration in unmanned helicopter spray field have not been studied. As a result, based on the large load for unmanned helicopter flight platform, we analyzed the performance

parameters of the unmanned helicopter, designed and perfected the unmanned helicopter spray system, setted up a big load digital eagle unmanned helicopter without plant canopy outside spraying process flow numerical simulation platform and sedimentary features. Spray field droplets drift mechanism of unmanned helicopter was studied , the working condition of unmanned helicopter spraying process was more optimizationed. by the resluts of field experiment , It provides the theory basis for the optimization design and guides the field test of unmanned helicopter spray system for large load device.

3. Basic numerical simulation of spraying

With the rapid development of computational fluid dynamics (CFD) and CFD software, good simulation conditions can be created for the flow and deposition characteristics test of unmanned helicopter spraying process. Through simulation test study can not only solve the uncontrollability of meteorological environment, but also through numerical simulation the influence of different variable factors on the droplets deposition characteristics, quantitative analysis and the simulation results under the condition of variable factors analysis prediction, simulation test results for large load Digital eagle unmanned helicopter guide optimization study of spray technology. Figure 1 is atomization angle with different atomization pressure

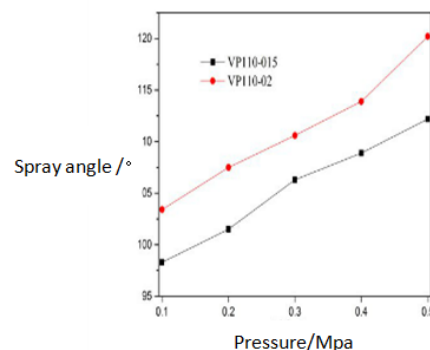| Type	sector nozzle： VP110-015					sector nozzle： VP110-02				
Pressure/Mpa	0.1	0.2	0.3	0.4	0.5	0.1	0.2	0.3	0.4	0.5
Spray angle /°	98.3	101.5	106.3	108.9	112.2	103.4	107.5	110.6	113.9	120.2

Fig 1 Atomization angle with different atomization pressure

The velocity distribution of the gas phase flow field in a large load plant protection unmanned helicopter is obtained by solving the n-s equation and turbulence equation based on unstructured grid. Figure 2 is Schematic diagram of outflow field. Discrete phase model (DPM), SST k-w turbulence equation and SIMPLE algorithm were used to calculate the motion trajectory and deposition distribution of discrete phase droplets in the gas phase flow field. The whole solution process involves the fluid dynamics n-s equation, the sst-w turbulence model and the droplet particle model.
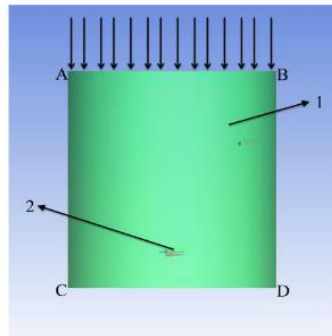
Fig 2 Schematic diagram of outflow field

As shown in the figure 3,a complete set of aerosol systems usually consists of a nozzle, a cartridge, a pump, a line, a spray rod and a support frame. According to the structure characteristics of the unmanned helicopter AK61, with the power of the unmanned helicopter as the power source of the spray system, atomizing spray nozzle symmetrical installed in rod on both sides, the plastic hose into the medicine cabinet, guarantee the security of the unmanned helicopter flight control of unmanned helicopter through the remote control system for the process of spraying atomization system of opening and closing.
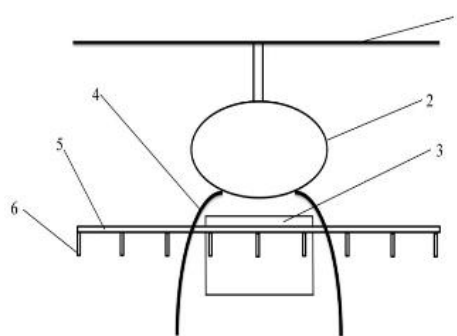

Fig 3 The sketch map of FR-200 plant protection unmanned aerial helicopter

(1) pump

Due to the limited load of the unmanned helicopter, the effective load of the aircraft can be increased by reducing the weight of the whole spray system. In order to study the characteristic parameters of nozzle atomization, the atomization pressure range was selected as 0.1~ 0.6mpa. According to the requirements of atomizing pressure, 12V dc driven micro diaphragm pump was selected, with rated power of 60 W, pressure range of 0 ~ 0.8mpa and maximum flow of 5 L/min.

Tal mean diameter of droplets with the increase of atomization pressure gradually decrease the main reason is that the pressure increases, increases the liquid inertia force, the inertia force and surface tension of liquid cancel each other out, reduces the stability of liquid membrane area and the initial kinetic energy of droplets increases with the increase of atomization pressure, greatly reduce the probability of droplets collide each other. The average diameter of sotel increases with the increase of the diameter of the fan-shaped nozzle, mainly because the length of the liquid film area increases with the increase of the diameter of the fan-shaped nozzle, the thickness of the liquid film also increases, and the stability of the liquid film area increases, resulting in the increase of the average diameter of the liquid film.

With the increase of atomization pressure, the flow rate of the nozzle increases and the flow rate of the nozzle is positively correlated with the nozzle width. Four fan-shaped nozzle fitting determination coefficients R2 can be obtained by fitting the flow data, which are 0.97688, 0.94445, 0.97237 and 0.97435, respectively. Assuming that the flow variable is u, unit mL, pressure variable is d, and unit Mpa, the linear fitting formulas of the four curves are u=217+713d, u=334+908d, u=417+1302d,

u=582+1695d, respectively. It can be seen from the above that the flow rate of the four types of fan nozzle is approximately linear with the change of atomization pressure.

Atomization Angle is one of the important characteristic parameters of atomization parameters, which can reflect the size of atomization field and is an important index of atomization system design and atomization effect evaluation. The measurement methods of atomization Angle mainly include the measurement of exit atomization Angle, the measurement of conditional atomization Angle and the measurement of atomization Angle according to the obvious straight part of the jet boundary.

The uniformity of spray distribution is one of the important parameters to characterize the effect of unmanned helicopter plant protection. The uneven distribution of spray is not only a waste of pesticides, but also a serious influence on the spraying effect. Therefore, this section USES the spray system spray distribution measurement platform to measure the uniformity of spray distribution of two types of fan nozzle.

The spray flux distribution was used to characterize the spray uniformity. The spray nozzle distance Lp and vertical distance Hc of the test stand can be adjusted. Open the spray system to allow the liquid to enter into different measuring cylinders through the liquid collection separator. The volume of the liquid in the measuring cylinder can be read to obtain the distribution law of the spray system.

The distribution of gas-phase flow field is one of the important factors affecting the effect of aerial spraying. Big load Digital eagle unmanned helicopter, spraying droplets are unmanned helicopter downwash flow downward and the extrusion of round, at the same time the helicopter flight flow field is a typical unsteady flow, and as a result of the rotor high-speed rotation, the rotor blades to flow rate changes over the azimuth Angle, strong blade tip vortex and produced by the rotation of rotor wake flow, caused the unmanned helicopter when spraying droplets of settlement and drift uncertainty increases, this chapter mainly studies unmanned helicopter rotor downwash flow field distribution features, It lays a foundation for studying the dispersion theory of aerosol droplets and the characteristics of multi-phase flow of aerosol, as well as exploring the law of droplet deposition and drift in the air when sprayed by unmanned helicopter.

(1) The total velocity of the hovering flow field of the unmanned helicopter basically presents a symmetry about the y-z plane. The total velocity first increases and then decreases along the direction of the rotor, and the maximum value is reached around x/R=0.8, and the maximum value is 20 m/s. Due to blocking the role of the fuselage, the body of the aeroplane directly disorder, velocity distribution in vertical direction speed is greater than 0, z = 3 m close to the ground, under the influence of ground effect, the vertical velocity gradient on the increase, with the height of the fall, the downwash flow field maximum speed gradually decreases, and the velocity distribution of leveling off. By defining the velocity inhomogeneity, the optimal installation position of the spray rod is obtained at the position of 1.25-1.75m below the rotor.

(2) The vertical wind speed of the monitoring points distributed along the rotor side of the unmanned helicopter's flight wind field basically shows a decreasing trend, and the vertical wind speed and wind speed change trend of the forward flying and backward unmanned helicopter are basically the same; With the increase of the flying speed of the unmanned helicopter, the front inclination Angle of the rotor increases and the vertical wind speed decreases. In the design of the spray system, therefore, the deposition amount of fog drops can be increased by increasing the spraying Angle of the nozzle. As the flight altitude increases, the vertical velocity of no. 1 monitoring point gradually decreases. The vertical wind speed decreases with the decrease of canopy height. When the forward flying speed v= 3m /s and canopy height hg= 1.5m, 1.0m and 0.5m, the wind speed at no. 1 monitoring point is 5.0m /s, 4.5m /s and 4.3m /s respectively, and the vertical wind speed at the rotor edge (no. 4 wind speed monitoring point) tends to be consistent.

4. Conclusion
By the plant protection   flight platform for unmanned helicopter, analyzed the technical parameters of the unmanned helicopter, completed the unmanned helicopter spray system each component selection

and design. the droplet size distribution of spray system were measured and analyzed the influence of different pressure of fan nozzle size spectrum, and measured   the spray system under different nozzle pressure flow.   use the   method of change   atomization Angle   to choose the spray atomization Angle, and determine the atomized spray system pressure is 0.3 Mpa. In addition, when the spray system pressure was 0.3mpa, the spacing between the two sprinklers was controlled as Lp=40, 50, 60, and 70 cm, and the vertical height between the sprinkler head and the separator was Hc=50, 100, and 150 cm, respectively. The spray fog distribution of fan-shaped sprinkler head vp110-015 and vp110-02 was measured, and the installation spacing of fan-shaped sprinkler head vp110-015 and vp110-02 was determined as 50 cm through the variation coefficient of spray fog distribution. 2. Ansys Fluent software was used to study the AK61 unmanned helicopter hovering wind field distribution characteristics and experimental verification, determine the scope of spray rod installation, spray distribution provides scientific basis for unmanned helicopter, and through the experimental study on the flight (former fly and inverted) in the process of plant canopy under different flight parameters of vertical distribution of wind field.

(1) The total velocity of the hovering flow field of the unmanned helicopter basically presents a y-z plane symmetry. The velocity first increases and then decreases along the direction of the rotor, and the maximum value is reached around x/R=0.8, and the maximum value is 20 m/s. Due to the blocking effect of the fuselage, the body of the aeroplane just below the velocity distribution is disorder,vertical speed is greater than zero. When the helicopter close to the ground   z = 3 m, due to the influence of ground effect, vertical velocity gradient on the increase, with falling height, the maximum speed gradually decreases, and the velocity distribution flattens out By defining the speed,The optimal installation position of the spray rod is within the range of 1.25~1.75 m below the rotor.

(2) The vertical wind speed of the unmanned helicopter flying wind field distributed along the rotor side of the monitoring point basically shows a decreasing trend, and the vertical wind speed and wind speed change trend of the unmanned helicopter are basically the same when flying forward and backward; With the increase of the flying speed of the unmanned helicopter, the forward inclination Angle of the rotor increases, and the downward wash flow field of the rotor increase with the inclination Angle of the vertical direction, resulting in the decrease of the vertical wind speed. Therefore, in the design of the spray system, the method of increasing the spray Angle of the nozzle can be used to reduce the evaporation and drift of fog drops during the spraying operation of the unmanned helicopter. As the flight altitude h increases, the vertical velocity of no. 1 monitoring point gradually decreases. The vertical wind field decreases with the decrease of canopy height. When the forward flying speed v= 3m /s and the canopy height hg=1.5, 1.0 and 0.5m, the wind speed at no. 1 monitoring point is 5.0, 4.5 and 4.3m /s respectively, and the vertical wind speed at the rotor edge (no. 4 wind speed monitoring point) tends to be the same.

5. Expectation

(1) To further improve the study on the distribution of flow and deposition characteristics in the spraying process of uavs with large load, and the study on the influence of different lateral airflow on the flow and deposition distribution rules of fog droplets in the spraying process of uavs.

(2) In the simulation calculation, the influence of factors such as different plant canopy and plant density on the flow and deposition characteristics in the spraying process of high-load plant protection unmanned helicopter was studied.

(3) To further improve,we can research on anti-drift sprinkler head, research on anti-drift mechanism of anti-drift sprinkler head and field experiment research on anti-drift sprinkler head.

References

[1]   Zhu Qiuyue, Chen Xiaobing. Talk on the Present Situation and Development Opportunities of Plant Protection Machinery in China [J]. Agricultral Equipments, 2007, 28(10): 9-11.

[2]   Zhou Zhiyan, Zang Ying, Luo Xiwen, et al. Technology innovation development strategy on agricultural aviation industry for plant protection in China[J]. Transactions of the Chinese Society of Agricultural Engineering, 2013, 29(24): 1－10..

[3]   He Kuixiong. Improving severe draggling actual ity of plant protection machinery and its application techniques [J]. Transactions of the Chinese Society of Agricultural Engineering, 2004, 20(1): 5-13.

[4]   Huang Y, Thomson S, Hoffmann W. Fritz. BK 2013. Development and prospect of unmanned aerial vehicle technologies for agricultural production management [J]. International Journal of Agricultural and Biological Engineering, (6) 1-10.

[5]   Teske M E. An introduction to aerial spray modeling with FSCBG [J]. Journal of the American Mosquito Control Association-Mosquito News, 1996, 12(2): 353-358.

[6]   Teske M, Thistle H, Londergan R. Modification of droplet evaporation in the simulation of fine droplet motion using AGDISP [J]. Transactions of the ASABE-American Societyof Agricultural Biological Engineers, 2011, 54(2): 417

[7]   Teske M E, Bird S L, Esterly D M. AgDrift®: A model for estimating near-field spray drift from aerial applications [J]. Environmental Toxicology and Chemistry, 2002, 21(3): 659-710.