Establishment and Simulation Analysis of Aviation Sprinkler Model

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Abstract: Aviation sprinkler extinguishing has the advantage of being less restricted by terrain and features, and has become the main fire extinguishing method for forest fires. Taking aviation sprinkler fire extinguishing as the background, considering the effects of wind speed, flying height and other factors on the effect of aviation sprinkler, a mathematical model of the location of aerial sprinkler watering point was established and simulated. The result shows that the aircraft should fly in parallel with the line of fire, and it is best to spray water at a wind direction of about 12m. This paper provides technical parameter support for improving the accuracy of aviation sprinklers.

Keywords: aviation, simulation analysis, sprinkler, fire extinguishing

I. Introduction

China is a country with frequent forest fires. Among the many factors that affect the forest ecological environment, fires have the most serious impact and damage on forest[1]. Compared with fire fighting on the ground, aircraft fire fighting has the advantages of being less restricted by terrain and features: First, it can save a lot of manpower, material and financial resources to carry out in forest areas with abundant water resources; Thirdly, it can directly control the intensity and spreading speed of fire; compared with the fire fighting methods such as attacking the ground with fire or setting up fire barriers, it can greatly reduce the loss of forest resources. Therefore, forest aviation fire-fighting technology has broad prospects and great promise. As far as the fire suppression situation at home and abroad is concerned, because fire trucks are mostly affected by geographical and environmental factors, they cannot quickly control the fire, resulting in serious loss of forest resources, and the personal safety of firefighters cannot be guaranteed. Therefore, the forest fires were extinguished after the disaster. Mainly rely on forest aviation to extinguish fires. Because chemical fire extinguishing agents pollute the environment, and water has an infiltrating effect on forests, it is the best choice to use water to extinguish forest fires. Today, when we attach importance to the harmonious development of ecological environment and human beings, water will be the direction of the development of forest fire extinguishing agents[2-3]. Helicopter bucket fire extinguishing is one of the most direct and effective ways to extinguish forest fires by water. It has the advantages of being free from traffic and terrain restrictions, more accurate watering, high fire extinguishing efficiency, economy and safety, and thorough fire extinguishing [4]. Helicopter bucket sprinkler technology is one of the more direct and effective fire extinguishing methods in the world. Wu Zepeng[5] and others used K-32 helicopter bucket watering effectiveness test experiments to show that the accuracy of the K-32 helicopter bucket sprinkler landing point accuracy has a great impact on the fire fighting efficiency. When the landing point is not accurate, the aircraft passes over the fire field. On the contrary, the temperature of the fire scene will rise sharply. Therefore, studying the location of the watering point is of great significance to the improvement of aviation fire extinguishing efficiency. J. H. Amorim conducted a set of real-scale drop tests using water and a wide range of fire retardant viscosities. The statistical uncertainty of the cup-and-grid sampling method is applied in the paper. And the ground pattern is authenticated. The results show that the mean squared is 0.001 and a Pearson correction coefficient is above 0.9[6]. Dominique Legendre considered the ground patterns of flow drops. The width and length of the flow drop action can be described through a simple relations, which include some factors that is designed by plane. Finally the drop area shows a Gaussian distribution [7].

II. Establishment of Aviation Sprinkler Model

A. Force analysis

The water that the aircraft spills from the air is affected by the following forces during the fall: first, the inertial force(F1), because the aircraft is flying at a speed, the sprinkled water has an inertial force that continues to "rush" forward; the second is gravity(F2), Water falls in the process of falling and is affected by the gravitational force of the earth. It belongs to free fall motion. The third is the wind force(F3). If the water is sprayed against the wind, the wind will give a resistance to the water that “rushes” forward. A horizontal thrust of the lower water causes the water to drift (displace) laterally. The resultant force(F) is formed under the effect of the above three forces, as shown in Figure 1. Its combined force(F), flying height (H), and the timing of opening the valve of the water-carrying device determine the position where the water falls to the ground, and therefore the accuracy of the sprinkler.

B. Water landing trajectory

After the water body is thrown from the fire extinguishing aircraft, it will perform parabolic movement in the air under the action of horizontal inertia and gravity. After a period of time, the water body will cover the fire area. Under the condition that the water thickness in the unit area meets the fire extinguishing requirements, the fire area is extinguished. The entire water-fighting process of the fire-fighting aircraft is shown in Figure 2. The aircraft starts watering from point O and ends at point B.

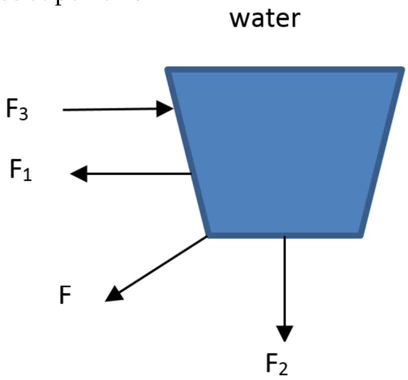

Figure 1 Force analysis

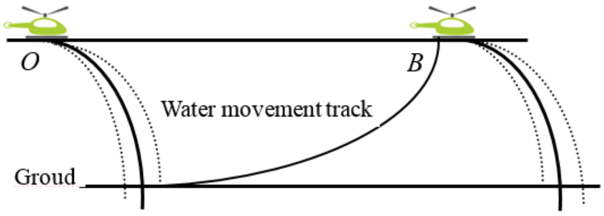

Figure 2 Fire-fighting aircraft watering process

The water body will be affected by air resistance and wind during the process of falling. The water body is greatly affected by wind force in the air. When the wind speed of the fire field exceeds 10 m/s, the cast water drifts seriously, which affects the accuracy of the cast water. Strong wind conditions are not considered here for the time being. Assuming that the water body landing time is t, the horizontal distance of the water body landing on the x-axis can be expressed as:

Quiet wind. Assume that when there is "no wind" on the fire field, you can directly spray water on the fire line or hover water on the fire point or smoke point. According to the flight speed and altitude, determine the timing of valve opening and watering.

Downwind. When the direction of the line of fire is parallel to the wind direction, the flight can be sprinkled against the line of fire, fire, and smoke directly against the wind.

Crosswind. In this case, there is a high requirement for sprinkler technology; when the wind direction forms a certain angle with the azimuth of the fire line, the water spraying of the route must be corrected so that the ground projection position of the flight route is at a certain distance from the position of the fire line. Watering accuracy is also affected by flight speed, altitude, and wind strength.

Water drops from the air in a free fall state, which is obtained from the free fall formula:

$$H = \frac{gt^2}{2} \qquad (1)$$

The wind speed is uniform at an instant, which is obtained from the uniform velocity displacement formula:

$$s = vt \qquad (2)$$

The wind speed gives a lateral thrust to the falling water, and the formula for the revised route distance can be derived:

$$s = v\sqrt{2H/g} \qquad (3)$$

Where,

s - The distance between the ground projection of the route and the line of fire, m;

v - Wind speed over the fire field, m/s;

H - Flying height, m;

g - constant, gravity acceleration, equal to 9.8 m/s2.

III. Numerical simulation

According to (3), the relationship between the correction route and the distance of the line of fire can be obtained at different wind speeds and flight heights, as shown in Figure 3.

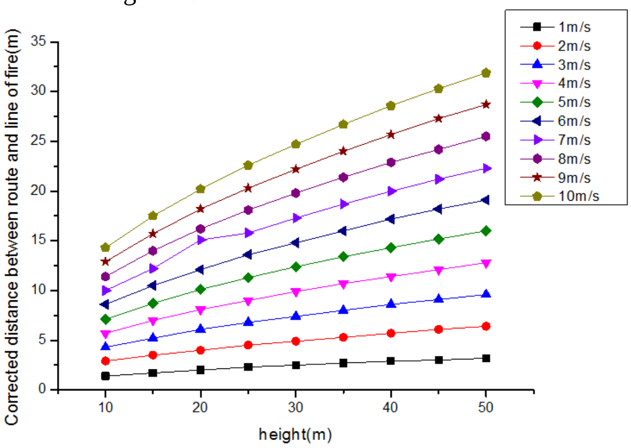

Figure 3 Relationship between wind speed, flight altitude, correction route and distance of fire

From the figure, it can be found that when the wind speed of the fire field is 5 m/s and the flying height is 30 m, the distance between the corrected route and the fire line is 12.4 m, that is, the aircraft should fly in parallel with the line of fire, and it is best to spray water at a wind direction of about 12m. This chart can be used as a reference for pilots to modify the sprinkler course.

IV. Conclusion

In this paper, an aerial sprinkler model is established, considering the influence of wind speed and flying height on the aerial sprinkler effect, and the relationship between the corrected route and the line of fire under different wind speeds and different flying heights is obtained. Because the accuracy of the water drop point has a great impact on the efficiency of fire fighting, it is of great significance to study the location of the water drop point to improve the efficiency of aviation fire suppression.

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