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Research Article

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Study on Fire Effectiveness of Modified Water Mist Extinguishing Pool under Simulation Space

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Abstract The water temperature and water mist extinguished the short-term temperature rise in the early stage of oil fire, which may cause oil pool fire splashing and affect the safety of fire extinguishing. A diol phenol and ethylene oxide condensate was selected. The nonionic liquid is modified as a fine mist additive. The comprehensive analysis of the kerosene fire was extinguished by modifying the characteristic parameters of water mist and the modified water mist with different mass fractions under the simulated fire extinguishing experiment platform. It is found that the surface tension is reduced and the specific surface area is increased after the modification of the water mist. With the increase of the mass fraction of non-ionic liquid in the fine water mist, the fire extinguishing time is shortened and the flame temperature is drastically decreased, and the fire extinguishing efficiency is better than that of the pure water mist. When the modified water mist extinguished the kerosene fire, there was no sudden rise in temperature and flame phenomenon under the action of pure water mist. The reason is: the mist of the modified water mist is reduced, the disturbance to the flame and the surrounding air is reduced, the flame zone is penetrated to the fuel surface, and the solubilization and emulsification of the non-ionic liquid attenuates the fuel splash phenomenon and surface temperature.

Keywords non-ionic liquid water mist; simulated fire extinguishing space; surface tension; temperature rise; fire extinguishing effectiveness

1. Introduction

Fire has become one of the most common disasters in human life that threaten public safety and social development. As a low-cost, environmentally friendly, efficient and environmentally friendly medium, water mist technology has become the main fire extinguishing technology [1].

The fire extinguishing mechanism of pure water mist includes: gas phase cooling, attenuating heat radiation, surface cooling, and oxygen isolation [2-3]. The four factors can reduce the burning rate during the fire extinguishing process, and the main advantage of the pure water mist fire extinguishing is that it can quickly and effectively extinguish the B fire, but the pure water mist will initially cause the oil pool fire to suddenly When a flame mass appears, the temperature will increase significantly [4]. For example, Mawhinney et al. [5] first reported that the initial release of water mist fire extinguishing, the heat release rate will suddenly rise, the cause of the steep rise may be due to the water mist disturbance caused by the water mist, so that the surrounding air acts on the pool. The fire burns and enhances the burning of the pool fire. Atreya A et al. [6] used a small-scale diffusion flame experimental platform to study the mechanism of pure water mist fire extinguishing. The results show that increasing the concentration of pure water mist can oxidize carbon monoxide in a large number of combustion zones to carbon dioxide. The flame temperature rises and the fire increases. Wang Xishi et al [7] first studied the interaction between water mist and flame by infrared full-field diagnostic method. It is believed that the reason for the rapid expansion of the combustion zone in the initial stage of water mist is the increase of the suction force between air and flame. Large, so that a large amount of air participates in the combustion reaction. Zhou Xiaomeng et al [8] found that the kerosene fire first increased and then decreased in the initial stage of pure water mist fire extinguishing through a small-sized cone calorimeter platform. Richard J et al. [9] considered that the fire-extinguishing ability of water mist is related to the droplet size and haze amount. As the pressure of the nozzle increases, the particle size of pure water mist decreases, the amount of fog increases, and pure water The ability to extinguish the fire of the fog is improved, but the effect of increasing the flame is reduced. Yao Bin [10] and others believe that when the water mist interacts with the pool fire, the strengthening and inhibition of the flame will be carried out at the same time. Especially for the fuel that cannot be completely burned, the flame strengthening phenomenon is more likely to occur when the water mist acts. Zhou Yang et al. [11] studied the effect of water mist fire extinguishing in different spray modes. It is difficult to extinguish the gasoline pool fire in the continuous water mist when the door is opened. Wu Jinxiang [12] and others believe that the flame strengthening caused by fuel splash is mainly: First, the larger momentum droplets pass through the flame zone, hitting the fuel in the oil pan, and the splashed fuel increases the effective contact area with the air, which improves. The vaporization rate of the fuel; secondly, when the fuel temperature reaches 100 ° C, the fine water mist that passes through the plume is heated and rapidly evaporates and expands. Therefore, in order to reduce the phenomenon of flame strengthening and temperature rise during the fire extinguishing process of pure water, the appropriate additives are selected to modify the pure water mist to improve the fire extinguishing ability of the pure water mist.

In this paper, a pure/modified water mist extinguishing kerosene fire experiment was carried out by using the hot state simulation fire extinguishing experiment system. The process of extinguishing kerosene fire by modified water mist and pure water water mist was observed through comparative experiments, and the modified water mist was analyzed. Under the action, under the different working conditions, the effect of modified water mist on the kerosene fire was discussed. The change of flame temperature, shape change and fire extinguishing time during the modified water mist fire extinguishing process were discussed. Then analyze the fire extinguishing efficiency of the modified water mist.

2 Water mist additive selection and parameter testing

2.1 Selection of water mist additive

According to the physicochemical properties of fine water mist additives, the types of water mist additives are mainly concentrated in inorganic salt compounds, foam additives and organic compounds [13-14].

(1) Inorganic salt compounds. Such compounds are mainly composed of a metal salt having good solubility, and the anions and cations produced by dissolving the metal salt in water can capture free radicals and interrupt the chain reaction in the combustion process, thereby improving the fire extinguishing efficiency. However, ions generated by ionization are likely to cause severe corrosion to metal pipes and equipment.

(2) Foam additives. The function of the foaming agent is to produce a large amount of foam covering the surface of the fuel, and to utilize the oxygen barrier and heat insulation effect of the foam to improve the fire fighting efficiency against re-ignition and fine water mist in the fire extinguishing process. However, the large amount of foam generated by such additives after fire extinguishing causes serious pollution to the environment.

(3) Organic compounds. Conventional organic additives such as urea, such as urea, dissolved in water, can reduce the effect of water mist extinguishing, but when used in closed fire, such additives pose a great threat to the personal safety of the fire. New organic additives such as sunscreens, surfactants, etc., improve the water mist fire extinguishing performance by improving the droplet size, shading performance and fog field effect of the fine water mist. Such additives not only improve the water properties, but also are non-corrosive to the equipment and environmentally friendly.

In summary, three organic compounds, alkylphenol ethoxylate, sorbitol, and alkyl alcohol amide, were selected to test the physicochemical properties of different compounds dissolved in water, and a non-corrosive, non-toxic, A non-polluting nonionic liquid is used as an additive for modifying water mist. The nonionic liquid is a condensate of an alkylphenol and ethylene oxide which can significantly reduce the surface tension of a fine water mist. And when the non-ionic liquid water mist acts on the kerosene pool fire, the "water-in-oil" function can disperse the oil in the water phase, and the water molecules enclose the oil molecules, thereby reducing the combustion of the oil and promoting the fire extinguishing effect [15].

2.2 Water mist characterization parameter test

Based on the surface tension ring test method, the surface tension of pure water mist and modified water mist was measured using a model KRUS-K100 surface tension meter. The particle size of the pure water mist and the modified water mist was measured by a phase Doppler laser tester. The droplet size distribution of pure water mist is 60-100, and the droplet size of 1%, 5%, and 10% modified water mist is distributed at 40-60, 35-55, 30-50, respectively. NFPA750 water mist standard, and when the water mist droplet size is about 50, the water mist has sufficient momentum to cover the oil surface through the combustion zone, and the droplets with small particle size evaporate quickly, thereby improving the fire extinguishing efficiency. [16]. See Table 1 for details.

Table 1: Characterization parameters of nonionic liquid water mist with different mass fraction

Extinguishing agent	ρ ($\times10^3$kg/m^3)	Surface Tension (mN/m)	Particle size distribution(um)	*I* ($\times10^{-10}$kg•m/s)
Pure water	1	69	60-100	3.3-15.2
1%	0.97	54.8	40-60	0.94-3.18
5%	0.968	41.3	35-55	0.63-2.4
10%	0.96	32.5	30-50	0.4-1.82

Among them, the amount of fog in Table 1 is calculated from the droplet velocity and particle size [17], and the momentum of the droplet can be obtained by approximating the following formula:

$$I = \frac{1}{6} n \rho_d \pi D^3 \sqrt{{v_x}^2 + {v_y}^2 + {v_z}^2} \quad (1)$$

Where I is the amount of haze, the unit is kg·m/s, n is the number of droplets, ρd is the density of water kg/m3, D is the droplet size, the unit is, vx, vy, vz is the droplet in three The velocity component of each direction, in m/s.

3. Simulation of fire extinguishing system and fire extinguishing situation

3.1 Simulation of fire extinguishing system

The experimental system includes a water mist fire extinguishing system, a flame temperature measuring system, a solution configuration unit, a data acquisition system, and the like. The water mist generating system consists of a standard confined space and a water mist fire extinguishing system. The standard confined space size is 3m x 3m x 2.8m. The water mist fire extinguishing system adopts a low-pressure water mist fire extinguishing system, which is composed of a centrifugal pump, a water tank, a pressure gauge, a nozzle, etc., and the modified water mist nozzle is 2.5 m high from the oil pan. The fuel used in the experiment was kerosene, and the fuel was placed in an oil pan having a diameter of 15 cm and a height of 6 cm. Four thermocouples are arranged vertically along the center of the oil pan. The thermocouple No. 4 is 5 cm away from the oil surface. A thermocouple is placed every 10 cm above the thermocouple No. 4, a total of three thermocouples are arranged, and then a paperless recorder is used. Perform real-time temperature measurement and observe changes in flame temperature.

Before the experiment, about 10 L of different mass fraction non-ionic liquid solutions that had been configured were placed in the water storage device and sealed and stored, and after several measurements before the experiment, the outlet pressure of the nozzle was measured to be 0.8 Mpa.

At the beginning of the experiment, the fuel pool fire was fired. After the oil pool fire was stably burned to 600 °C, a fine water mist was applied, and then the time for extinguishing the kerosene pool fire was started. After the flame was extinguished for 30 s, the centrifugal pump switch was turned off. Open the smoke exhauster for smoke exhaust. After 60s, the fuel in the oil pan is not re-ignited, which means that the fire is successful. According to the experimental conditions, repeat the above steps, collect data and conduct comparative analysis.

3.2 Analysis of fire time of modified water mist

The fire extinguishing time is one of the important parameters reflecting the fire extinguishing efficiency. The fire extinguishing time is compared and analyzed according to the fire extinguishing efficiency of the non-ionic liquid water mist at different concentrations. In the simulation experiment system, the stopwatch is used to record the time of extinguishing 100g kerosene and the fire extinguishing time.

The relationship between the extinguishing time of the modified water mist extinguishing kerosene fire and the mass fraction of non-ionic liquid additive was compared. It can be seen that the time of kerosene fire extinguishing under the action of pure water mist is 231s. When the mass fraction of modified water mist is 1%, 5%, 10%, the time of kerosene fire is 50s, 19s, respectively. 16s. It can be seen that as the mass fraction of the modified water mist increases, the fire extinguishing time is continuously shortened. When the mass fraction of the modified water mist is 1%, the fire extinguishing efficiency is 4.62 times that of the pure water mist. As the mass fraction of the modified water mist continues to increase, the fire extinguishing time is further shortened, but the fire extinguishing time varies little. The experiment proves that the modified water mist has achieved good fire extinguishing effect when the mass fraction is 5%, and the fire extinguishing efficiency is 12.16 times of the pure water mist. Further increase in the mass fraction has limited the reduction in the time to extinguish the fire.

3.3 Effect of modified water mist on flame temperature

The temperature curve of the pool fire flame measured by four thermocouples at the same position under the action of pure/modified water mist. It can be seen from the fire water of pure water water mist that the whole fire extinguishing process is divided into three parts, namely t1, t2 and t3. During the temperature rise phase in the t1 phase, the fuel in the oil pan is fully burned, and the flame temperature rises sharply. When the temperature reaches about 600 ° C, the nozzle is opened to release a pure water mist. During the t2 phase, the temperature collected by the three higher thermocouples from the fuel center drops sharply, but the temperature of the thermocouple collected closest to the fuel surface does not decrease immediately, but a sharp rise that first drops and then rises. phenomenon. Finally, during the temperature decay phase (t3), the temperature tends to slowly decrease.

It can be seen that the 5% modified water mist fire extinguishing only experienced two stages of temperature rise phase (t1) and temperature drop phase (t2). The thermocouple closest to the fuel center did not show a sharp rise, but the temperature collected by the four thermocouples showed a sharp decline, and the rate of decline was faster than that of pure water mist.

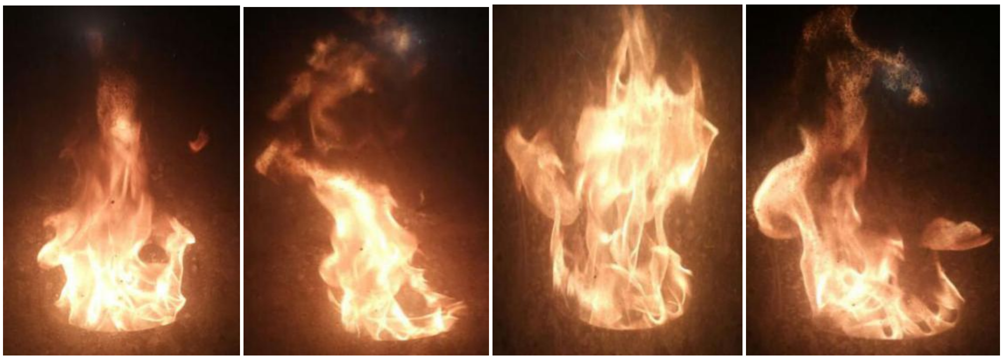
When the pure/modified water mist acts on the kerosene pool fire, the temperature curve of the pure water mist has a large change and the decline is slow, while the temperature curve of the modified water mist changes little and drops rapidly. Therefore, after the modification The cooling effect of the fine water mist is better than that of the pure water mist; the reason why the temperature rises sharply after the application of the fine water mist in the pure water mist fire extinguishing process is: the droplet size of the pure water mist is large, Sufficiently large amount of fog, the water mist is released to disturb the change of the surrounding flow field, so that the surrounding oxygen is drawn into the flame zone, and the flame is in a state of intense turbulent combustion.

When the 5% modified water mist is used for fire extinguishing, the temperature rise phenomenon disappears and the falling rate is fast. First, the addition of the non-ionic liquid additive reduces the surface tension of the water, and the droplet size becomes smaller. The relative surface area is increased, and the modified water mist rapidly vaporizes to form water vapor when passing through the combustion zone, absorbing a large amount of heat in the space; secondly, a part of the suspended mist has a relatively small amount of modified fine water mist to capture oil and gas molecules, and is wrapped The oil and gas molecules are isolated to isolate the oil and gas molecules from reacting with oxygen. Third, the modified fine water mist with relatively large amount of fog moves through the flame zone and is concentrated on the fuel surface to form a dense foam layer, which is not only good for isolating kerosene, but also for inhibiting kerosene. Evaporation, reducing the source of combustibles, while reducing the thermal feedback and thermal radiation of the kerosene to the kerosene, allowing the kerosene to be fully cooled until the flame is completely extinguished.

3.4 Effect of modified water mist on the shape of flame

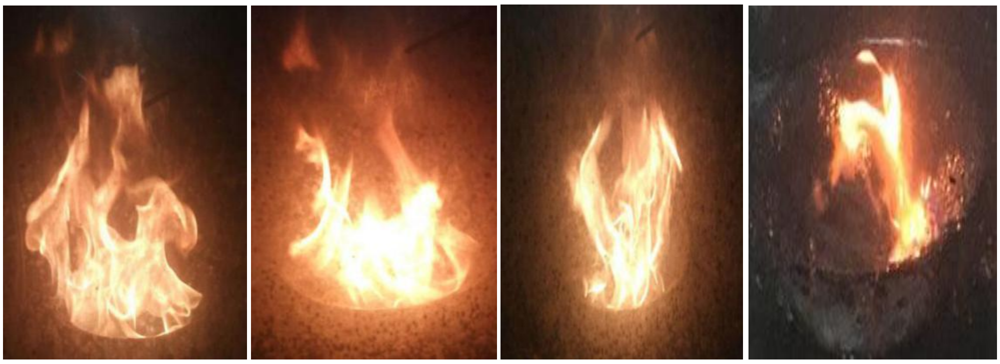
Figure 2 and Figure 3 show the shape of the flame taken after recording with pure digital water mist and 5% modified water mist extinguishing process using a digital video camera. From the figure, we can see the shape of the flame at different times. In the early stage of applying pure/modified water mist, the fuel is fully burned and the fire is enhanced. After applying pure water mist for 20ms, the direction of the water mist release is the same as the upward combustion. The flame interacts and the flame is pressed against one side of the oil pan (Fig. 2(b)); the application is continued for 40ms. Due to the large amount of fogging of the pure water mist, the flame volume suddenly rises when it hits the fuel surface through the flame. Increasing [18], the disturbance is enhanced, and the effective combustion area between the flame and the oxygen becomes larger, the brightness and height of the flame increase, the combustion of the pool fire is strengthened, and the flame is expanded to form a flame mass (Fig. 2(c)). The resulting temperature suddenly rises, which corresponds to the steep rise in the temperature curve. Further applying a fine water mist to 1 s, the flame height and brightness gradually decrease.

However, in Fig. 3(b), the application of the modified water mist directly suppresses the formation of the flame; when the modified water mist is applied for 40 ms, the flame brightness and height are rapidly lowered, the fire is weakened, and no flame is formed; further application is performed. By 1 s, the flame is torn into small flames, and a large amount of modified water mist wraps the small flame mass, blocks oxygen, and attenuates the burning of the kerosene fire.



(a) Before application (b) 20ms (c) 40ms (d) 1s

Figure 4: The shape of the flame during applying pure water mist



(a) Before application (b) 20ms (c) 40ms (d) 1s

Figure 5: The shape of the flame during applying 5% modified water mist

4. Conclusion

(1) By analyzing the characteristic parameters of the modified water mist, it is proved that the application of the non-ionic liquid additive reduces the surface tension of pure water, makes the specific surface area of the fine water mist larger, and improves the evaporation rate and suction of the fine water mist. Thermal capacity.

(2) In the process of modified water mist fire extinguishing, with the increase of the mass fraction of modified water mist, the fire extinguishing time is shortened and stabilized, and the fire extinguishing efficiency is better than that of pure water mist; pure water and fine water When the temperature of the mist is

extinguished, the temperature rises sharply and the phenomenon of the flame group is suppressed. When the modified water mist acts on the kerosene pool fire, the flame group is suppressed and the temperature drops sharply.

(3) During the modified water mist fire extinguishing experiment, a large amount of suspended modified water mist formed a package structure to capture the vaporized oil and gas molecules, and enclose the oil and gas molecules in the middle to block the heat exchange between the oil and gas molecules. The modified fine water mist with a large amount of fog moves through the flame zone and is concentrated on the surface of the oil to form a dense foam layer, which isolates the contact of combustibles with oxygen and reduces the combustion reaction.

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