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Numerical Simulation of Water Mist Fire Suppression Technology

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Abstract

The paper introduced the progress in research and application of electronic ultrasonic water mist fire suppression technology. Several researches showed that the electronic ultrasonic water mist can be as effective as the now-banned gaseous fire suppressant halon 1301. With the further research about electronic ultrasonic water mist technology, there must be more and more electronic ultrasonic water mist extinguishment tools applied in the fire suppression.

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1. Introduction

With the social and technological development, a variety of new materials, new energy, new processes, new technologies are emerging, and widely used, this will bring to human beings not understanding the many complex and new fire control problems, current and Fire in the coming period will be very severe situation is still urgent need for new fire fighting techniques.

Water possesses many attributes of the ideal fire suppressant. It is non-toxic, non-corrosive, ubiquitous, and has no adverse environmental effects. Application of water in smaller droplets (diameters below 300μ) offers several advantages [1]. Water mist droplet has small size, large surface area. The surface heat transfer coefficient has large value. When the ambient temperature rises, can quickly vaporize. Numerous small water droplets absorb heat rapidly in a short time. From the laws of thermodynamics: when one gram of water increases by $1\text{ }^{\circ}\text{C}$, 1 card heat would be absorbed in this progress; when 1 gram of water vaporizes, about 600 calories would be absorbed. So, the role of vaporization of water mist fire can quickly reduce temperature. Meanwhile, the inerting effect of water mist like the physical effect of physical gas fire extinguishing, could reduce the oxygen concentration. In addition, water mist has a very excellent blocking performance of thermal radiation transfer, can effectively block the intense heat radiation.

2. Extinguish mechanism and research leading edge

2.1. Fire risk analysis and combustion mechanism

Burning of any material must be equipped with the following three conditions: fuel, oxidizer (combustion-supporting material) and temperature (ie, sources of ignition). Three burning elements: fuel, combustion properties (usually oxygen) exposure, and reaching ignition temperature. The open fire must have "unchecked chain reaction". Fire fighting methods are the following: isolation and combustion properties, role of fire asphyxia; temperature drops below the fire, cooling the fire. There is also: Chemical inhibition of fire, isolate the role of fire, fire off a chain reaction and so on. Choking mist that can play a role, but also cooling down the environment, isolation, thermal radiation, with good prospects [3]. Water mist in the application of fire began in the 20th century, 40 years, which was mainly used in special places, such as transport and so on. Now because of environmental issues, fire extinguishing agents to be phased out, and water mist as a fire extinguishing agent for the potential advantages of no pollution to the widening of the scope of application, water mist fire extinguishing systems for residential buildings, flammable liquid storage facilities And electrical equipment, research, encouraging results have been achieved, is the fire science and cutting-edge research over the past decade one of the hotspots.

2.2. Research leading edge

A lot of research was carried out about water mist in the domestic. The basic research was carried out aimed at the properties and for water mist fire suppression and mechanism of the liquid-fire suppression by university of Science and Technology of China, State Key Laboratory of Fire Science[4], using the cone calorimeter system of a liquid combustible material samples of heat Release rate, combustion temperature, gas composition and combustion parameters before and after the change of water mist, the use of thermal imager system, thermocouples, heat flux meter cameras and other instruments of the fine mist of liquid and Interaction of solid diffusion flame around the flame structure were studied. Liao Guang-xuan, who also studied the results of water mist fire suppression in the electrical environment. Chow W K. [5], Hong Kong Polytechnic University as the flue gas and air are the two quasi-steady-state level, the establishment of the interaction of water spray and smoke layer one-dimensional mathematical model and predict the effect of smoke water spray parameters were studied.

U.S. Naval Laboratory (NRL) [3]on the low-pressure water spray, high pressure and high pressure water mist two-phase single-phase three kinds of water mist fire extinguishing system in a series of comparative test results show that: single-phase high-pressure water mist fire extinguishing system has the best results. The U.S. naval vessels and ships in Promoting the application of high-pressure single-phase water mist system. And in 2002, NFPA issued a standard on water mist extinguishing system NFPA750, this standard has been around the world in developing national standards for water mist fire suppression as an important reference.

Germany fog special company (FOGTEC) high-pressure water mist fire extinguishing system in the production and R & D is a world leading level. FOGTEC high pressure water mist fire extinguishing systems to pure water as the extinguishing agent, at 80 ~ 200bar water under high pressure into a mist, can be effective and safe to fire. FOGTEC production of fire extinguishing system has passed the Tianjin Fire Research Institute's certification "State of fixed fire extinguishing systems and fire-resistant components of Quality Supervision and Inspection Center" may apply to the Chinese market.

3. Characteristics of water mist fire suppression

- (1) Suitable for many kinds of fire: can be put out A, B, C class categories and electrical fires.
- (2) High efficiency [5]: The water consumption is only 1% of the traditional fire hydrant to 5%, the efficiency of the traditional fire 100 to 200 times.
- (3) Cooling down smoke effect: water mist evaporate immediately when meet fire, rapid cooling, cooling rate faster than 100 times the sprinkler system; to purify the smoke and emissions, improve visibility, reduce smoke particles damage the human body, conducive to the safety of fire-fighters in the fire evacuation and rescue work.
- (4) Easy to operate: with the traditional operation method similar to the fire hydrant may be close to the fire put out the fire.
- (5) Less water damage: to avoid a lot of water damage to the equipment and the secondary pollution of the environment, and is conducive to the fire scene investigation and evidence collection.
- (6) Safety and environmental protection: only water as the extinguishing agent, the environment, protection of objects had no damage and pollution; in stand-by state for the atmospheric pressure, routine maintenance work and costs greatly reduced.

4. 4 Simulation of water mist fire suppression in a confined Space

4.1. FDS fire model

Limited space model for the living room to modify the example comes from FDS, shown in Figure 1. The size of the simulated space is set to 5.2m × 6m × 3.5m (length × width × height). The fire area is 0.1m × 0.1m located in the left side of the sofa, Non-steady fire was selected in simulation, with t2 type of fire to approximate the unsteady fire, the fire intensity can use formula: $Q = a * t^2$ (kW). The maximum heat release rate $Q = 1200\text{kW}$, 140s reached the maximum, and remained unchanged to the 420s.

Central ceiling in the room (left), the department has a 0.1m water mist nozzles, middle of the floor above the room, three thermocouples were set, named as T1, T2, T3, and the height is 1.5m, 2.5m, 3.5m.

The accuracy of numerical simulation of the grid is set to 0.1, that grid is divided into 50 × 60 × 30, a total of 120,000 grids. Simulation time is 420s. Model simulation uses mixture fraction combustion process, and Eulerian - Lagrangian model was adapted to simulate the interaction of water mist with the flame.

Smokeview 5.5.6 - Jun 22, 2010

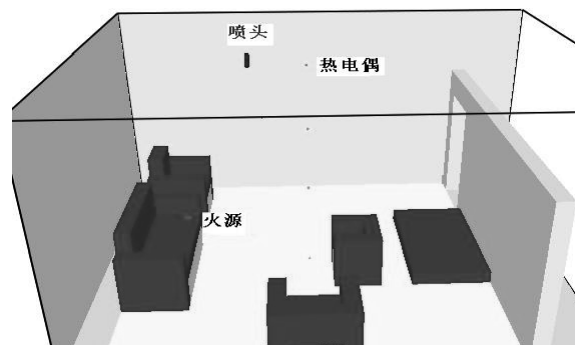


Fig.1 Model of water mist fire suppression in a confined room

Table 1 FDS modeling water mist sprayer parameter

Modeling Command	Discribe	Unit	Parameter Set
K_FACTOR	Discharge coefficient	L/min/ atm ^{1/2}	0.7
ACTIVATION_TEMPERATURE	Activation temperature	°C	74
OPERATING_PRESSURE	Operation pressure	MPa	1.4
OFFSET	Atomization distance	m	0.2
BEAD_DIAMETER	Bead diameter	um	300
DROPLET_VELOCITY	Droplet velocity	m/s	50

4.2. Simulation results

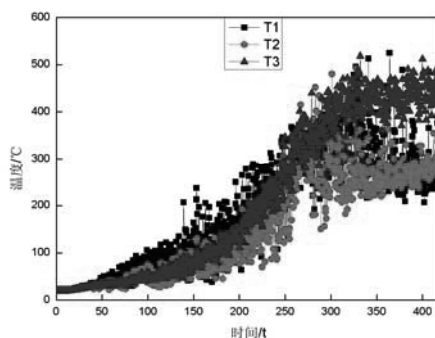


Fig.2 Temperature of different heights monitoring points (not installed fire extinguishing system)

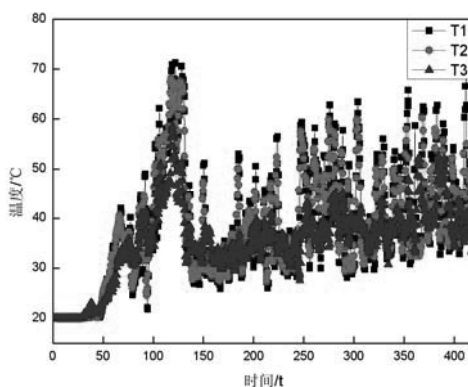


Fig.3 Temperature of different heights monitoring points (fire extinguishing system installed)

Makeup air area of the room $0.3\text{m} * 0.5\text{m}$, into the wind speed is $0.1\text{m} / \text{s}$, smoke exhaust opening size $0.2\text{m} * 0.2\text{m}$, exhaust speed is $0.3\text{m} / \text{s}$. Figure 2 shows that the temperature of the three measuring points continued to rise, the temperature of measuring point 3 whose height is 3.5m reached $500\text{ }^{\circ}\text{C}$.

It can be seen from Figure 3, 120s or so, the room at the top of the flue gas temperature of 3.5m at the $74\text{ }^{\circ}\text{C}$, then mist started, the temperature began to decline rapidly, the average temperature after the base at $40\text{ }^{\circ}\text{C}$ fluctuate.

By comparing Figure 2 and Figure 3, it is obvious that water mist fire can quickly control the temperature of confined space.

5. Conclusion

The mechanism of fire, burning of any material occurred must have the following three conditions: fuel, oxidizer and temperature. Water mist system can well be the two essential conditions for the fire, "oxidant and temperature" removal, effectively extinguish fire. For the confined space fires, water mist technology has very good control of fire and fire effects, water mist fire can reduce the ambient temperature and heat flux.

Its high efficiency of water mist cooling, pollution-free, low cost, water consumption, additional small and easy to clean water damage, etc. in the fight against A, B, C and K show a unique class of fire extinguishing capability. Therefore, water mist has been used in many fields. It can be applied to the fire protection of residential, ancient buildings, libraries, electronic equipment rooms, and aerospace.

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