Design and application of an aided water mist sprinkler tool in half-confined room

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Abstract. The object of this work was to improve water mist cooling effect in half-confined room. Firstly, the relative water mist standards on fire extinguishing were reviewed. Secondly, the aided water mist sprinkler tool on cooling with different separation distances and setting angles was designed. Thirdly, the cold spraying experiments were carried out and the working parameters were determined in model tunnel as half-confined room. These parameters for cooling were different from the parameters for extinguishing because of different targets. The further study should focus on the examination on cooling effect in actual fire experiment.

1. Introduction
Water mist system could be used to put out the fire in a confined room or half-confined room. With the help of fine misting nozzle, a stream of distilled water was broken up and formed the mist [1]. This mist was completely non-toxic. This system could be applied with the way of total flooding to extinguish the fire. During this progress, the water mist could absorb toxic smoke and take away the heat. The target fire included Class A, Class B and Class E except the combustion which had a chemical reaction with the water. In all, the water mist had both the fire-fighting performance and cooling performance [2].

Table 1. The substance which had a chemical reaction with water.

| The main type              | The detail substance          |
|---------------------------|------------------------------|
| 1                         | Active metal                 |
|                           | Li, Na, K, Mg, Zr.           |
| 2                         | Combustible gas              |
|                           | Liquid natural gas.          |
| 3                         | Solid deep-seated fire       |
|                           | Cotton bales, paper bag.     |
| 4                         | Others                       |
|                           | P2O5.                        |

2. Relative water mist standard for fire-fighting
The water mists were divided into three types including low pressure water mist (<1.2 MPa), middle pressure water mist (between 1.2 MPa and 3.45 MPa) and high pressure water mist (>3.45 MPa). One performance of the water mist was extinguishing fire [3]. To control and put out the fire, the water mist spray intensity and sprinkler spacing should be determined. According to GB50898-2013, these parameters were relative with the factors including application area, nozzle working pressure and setting height.
3. Design of aided water mist sprinkler tool for cooling

3.1. The aided water mist sprinkler tool

The other performance of water mist was cooling down the environment’s temperature. To determine relative parameters, the aided water mist sprinkler tool was designed with main water mist tube, branch water mist tube and adjustable support. Firstly, the whole length of main water mist tube was 3 m and the length of branch water mist tube was 0.5 m. There were four branch water mist tubes with the sprinkler spacing 1.5 m, 2.0 m, 2.5 m and 3.0 m. During one experiment, any two of the branch end sprinklers should be working together. The other left sprinklers should be plugged including the pressure gauge. Secondly, the distance between the sprinkler on the end of branch water mist tube and the wall could be adjusted by changing the setting angles between the wall and the branch tube. During this progress, the adjustable support including inside small solid tube and outside big hollow tube could be stretched. Thirdly, all the tubes were made of the pressure tube, which could stand for more than 10 MPa.

![Figure 1: The aided water mist sprinkler tool.](image1)

3.2. The nozzle type

![Figure 2: The XSW-T1.2/10 CA 001-020.](image2)

The sprinkler nozzle spray angle was 145° with $K = 1.2$. If this nozzle was working at the pressure 2.0 MPa, the flow rate would be $5.4 \text{ L/min}$ to one nozzle. The droplet diameter of this water mist was less than 0.4 mm, which meant the effect could meet the normal demands on water mist [4].

$$K \times (10 \times \text{Pressure})^{0.5} = 1.2 \times (10 \times 2)^{0.5} = 5.4 \text{ L/min} \quad (1)$$
3.3. The combustion model frame
To determine the cooling effect of water mist in half-confined room, the target combustion should be designed [5]. The model tunnel with 6 m height and 28 m length was built as half-confined room. The target combustion model frame with the height 2.5 m was finished using flame-retarded wood. This height was used to simulate the freight train or passenger train’s height, whose freight carriage or passenger carriage exclude the roof was about 2.5 m height.

![Combustion Model Frame](image)

Figure 4: The combustion model frame.

4. The cold spraying experiment
The cold spraying experiments were carried out to determine the relative parameters. If the working pressure was high enough, the sprinkler spacing 3 m would also be able to form whole flooding. If the working pressure was lower, the sprinkler spacing should be decreased. To distance between the sprinkler and the wall, the angle of branch tube and the wall could be adjusted by stretching the adjustable support. If the water mist was enough to extinguish the fire, all the angles should be enough to form whole flooding. But to cool down the environment’s temperature, the water mist flow rate should be decreased further [6]. After the experiments, the parameters were determined with spray angle 60°, spacing distance 2.5 m, pressure 2.5 MPa, height 3 m and spray intensity 1.1 L/(min·m²). The spray intensity was lower than the standard’s spray intensity 2.0 L/(min·m²), therefore the actual cooling effect should be verified by actual fire experiment in confined room like model tunnel [7] [8].
5. Conclusion
In this paper, an aided water mist sprinkler tool was made with combustion model frame and nozzle. Using this tool the water mist sprinkler parameters including spray angle, spacing distance, spray intensity were determined. These parameters to cool the temperature were different from the parameters in standard to extinguish fire. The further study should focus on the examination of the cooling effect of this water mist sprinkler parameters in actual fire experiment.

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