Experimental Study on Wood Crib Fire Suppression of Water Mist with additives

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Abstract—To improve the fire suppressing efficiency of water mist, we do experimental study on the wood crib fire suppressing by water mist with additives in a confined space. In the condition of constantly changing of pressure in water mist nozzle and the unchanged fire, fire suppressing performance of water mist with different additives were analyzed and contrasted by changing the type and the concentration of additives as well as the ratio of composite addtives. The experimental results show that the adding of additives can obviously improve the fire suppressing performance of water mist, different concentration of different addtives can cause many differences in fire suppression performance, and there exists their best concentration or the optimal proportion. In our experiment,it has the possibility of fire catching again, for the ability of suppressing a naked flame is well, but the control capability on fixed carbon combustion are inadequate.

Keywords-Water Mist; Wood Crib Fire; Fire Suppression; Additives

I. INTRODUCTION

As people's stengthen of environmental protection consciousness, the fire suppressing by water mist become a hot researching direction in the field of fire science. But it's difficult for normal water mist to suppresse the wood crib fire or the flame happening under the protection of a barrier. In order to expand the application scope of water mist, further more, to improve the efficiency of fire suppression by water mist, there are many research works for water mist with additives on fire suppressing technology in domestic or abroad. On the basis of the relevant research data at domestic and abroad, we carried on experimental study of water mist with additives for wood crib fire suppressing performance.

II. EXPERIMENTAL DEVICE

A. The water mist generator(shown as figure 1)

The water mist generator is composed of the following sections:

(1)Storage water tank.

It's the experimental water provider. To convenient for the modulation of the additive's concentration in experiment, we choose the tank which size is 1000mm*1000mm*1000mm.

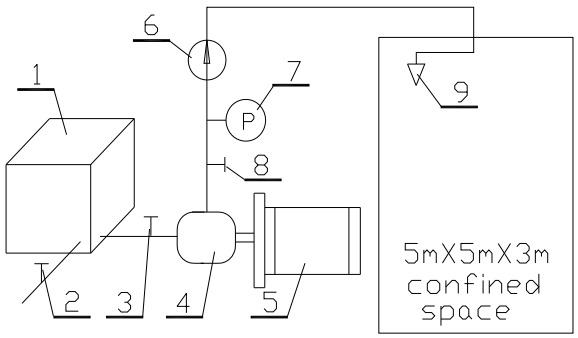
(2)High pressure water pump.

Provide high pressure water for the system using. Due to the expenses consideration, the cost of the high pressure plunger pump are expensive, so we choose the hydraulic gear pump which the highest press can reach to 20MPa.

(3)Water mist nozzle.

Water mist nozzle is an essential component of the water mist suppressing system. We select the water mist nozzle named XWT_B04 manufactured in Shanghai Jindun Fire Safety Equipment Co. Limited. This kind of nozzle is a combination of several Oblique centrifugal atomizing small nozzles. Compared with another nozzle, this nozzle has some features like suitable radius and large for kinetic energy of droplet.

(*4)Other accessories in system like pipes in high pressure or strainers, etc.*



1 storage water tank 2 drain valve 3 needle valve 4 water pump
5 electric motor 6 flowmeter 7 pressure gauge
8 pressure regulator valve 9 nozzle

Figure 1. Diagram of the water mist generator

B. Fuel and combustion device

The experiment is proceeded in a confined space which size of 5m*5m*3m, to gain a good observation of the phenomenon in the experiment, glass wall consist of stainless steel frame and tempered glass are placed around the confined space. The nozzle installed on top of the confined space, is situated just above the combustion source, and is 2.8m higher than the ground. The fuel in our experiment are called wood crib which consist of several woods each sectional dimension is 20*20mm,and 25-30cm in length, we put these wood crib on the oil pan and use diesel for ignition.

C. Measuring and recording equipment

（1）The temperature measuring system

To analyses the effect of water mist on the wood crib fire, we use thermocouples to measure the temperature of the key point near the wood crib fire. According to the set up of the equipment, we come up with a method of assigning numbers to different thermocouples. We assign number one to the thermocouple which the straight height to

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the ground equals 0.3m, assign number two to the one which the straight height to the ground equals 0.15m, and also assign number three to the one that located at the surface of the wood crib, assign number four to the one located at the center of the wood crib. The temperature of the experiment will be record by a data acquisition system connected with a computer.

(2)The pressure measuring system

Pressure measurement using 2 pieces of YTN-series of pressure gauges which precision grade of 1.6. To monitor the pump outlet pressure, pressure gauges which range of 40MPa are installed at the exit of the pump; pressure gauges which range of 16MPa are installed at the exit of the pump to monitor working pressure of the nozzle.

(3)The flow measuring system

There are two same types of flow meter located among the system, in front and after the section of the water mist system respectively to make sure the correction of the measuring of the flow, thus we can take the average if the numerical value are not differ greatly.

(4)Experimental phenomenon recording

All kinds of phenomenon in the experiment will be record by a camera which are connected with a computer

(5) Fire suppression time measurement

Extinguishing time is an important parameter reflects fire suppressing performance. We use stopwatch to record fire extinguishing time under different conditions. In the experiment, we measure the temperature by visual combining with the thermocouple measurement, especially the temperature value in the center of the wood crib to determine whether the fire has been suppressed. Let both timing and the release of water mist stop when fire suppression was convicted be done. Set the suppression time as the water mist applying start to the water mist imposing ending.

III. CHOICE OF THE ADDITIVES

A. Common types of additives and their extinguishing mechanism

Although there are a great variety of additives, the water mist additives are used to alter the physical or chemical properties of water mist. We use physical additives in order to change the physical properties of water and then improve the fire suppressing performance, such as increasing water wetting, adhesion and viscosity, etc. We use chemical additives in order to change the chemical properties of water, such as capturing free radicals in fire by metal ions in additives, terminate chain reaction process of flame, etc. However, some additives have both physical and chemical effects.

B. Choice of the additives

Wood crib fire belongs to the fire of class A, the most important thing for water mist in this kind of fire suppression is the ability in fuel surface cooling and the ability to penetrate the flame, we generally add a small amount of surfactant and thickening agent to improve it. Chemical additives achieved the purpose of fire suppression mainly by ceasing the chain reaction of the flame combustion. Chemical additives can be chosen for both fire of class A and class B. In conclusion, in this experiment, cheap NaCl, $NaHCO_3$ are chosen for the chemical additives, Sodium Dodecyl Benzene Sulfonate (SDBS in later) is chosen for the physical additives. Composite additives adopt the combination of NaCl and SDBS.

IV. RESULTS AND ANALYSIS OF EXPERIMENT

A. Water mist on fire suppressing experiment without additives

To determine the fire suppressing effect, firstly we should do non-additives experiment to determine fire suppressing performance of different additives by comparison. The pressure of our experiment is 4MPa, the weight of wood is 1 kg, release the water mist when the pre-combusting time to 7 min (the same experimental conditions latter). The temperature changes are shown as figure2. The fire suppression time cost 78 seconds.

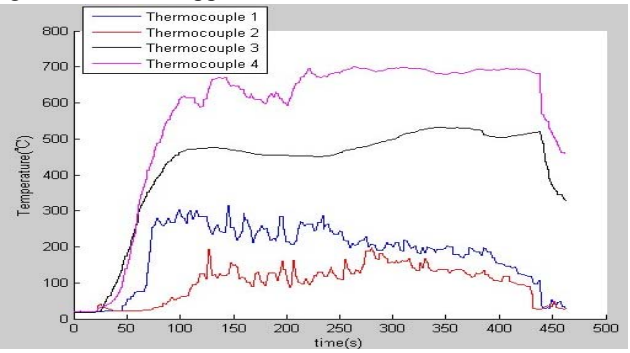

Figure 2. Temperature changing curve without additives

B. Water mist on fire suppressing experiment using physical additives

Through access to relevant information, we selected three kings of concentration of SDBS solution for this experiment, they are 0.2%, 0.4%, 0.6% respectively. Due to the space limited, this paper only gives the fire temperature change when the concentration was 0.4%, as shown in the figure 3. The experimental results and comparison are shown in table 1.

Table 1 Fire suppressing experiment by water mist containing SDBS

Concentration of SDBS	Nozzle pressure （MPa）	Precombustion time（Min）	Fire suppressing time（s）
0	4	7	78
0.2%	4	7	24
0.4%	4	7	9
0.6%	4	7	12

The experimental results show that after the adding of surfactant into water mist, the fire suppression ability is improved obviously. The results also reflected that the view of ‘the higher the concentration of the additives, the better ’is wrong, actually the concentration should has a

critical value. When the additive concentration is at a certain critical value, the best effect of fire suppression came, below or above this value will cause the effect drop. Generally, the mainly effect of physical additives is to reduce the surface tension of water., increasing water wetting force of material, prolong the affection time of water, thus improve the cooling efficiency. In theory, the fire suppression efficiency comes to the highest when the solution surface tension access to the minimum. Relevant data shown that the surface tension of SDBS gradually reduce with the increase of concentration, but it can hardly change with the increase of concentration when the concentration increases to a certain value, the concentration is 0.014 mol/L at 20℃, mass concentration is about 0.48%. So it can be seen from the experimental result that when the concentration of the surfactant come to 0.4% the fire suppression effect come to the best. But when the concentration of the surfactant come to 0.6% the experimental result isn't very good, this result has some difficult to understand because when the surfactant concentration is increased, solution surface tension basically no longer changed instead of increased while in theory. According to the fire suppression mechanism of physical additives, when the concentration of the surfactant came to 0.6%, the fire suppression won't be down. We guess it probably because that when the concentration of solution increasing, the viscosity increased accompanied, lead to an increase of the fluid flow resistance as well as reduced flow. But the above is just speculation; we believe that this issue requires further study in more depth.

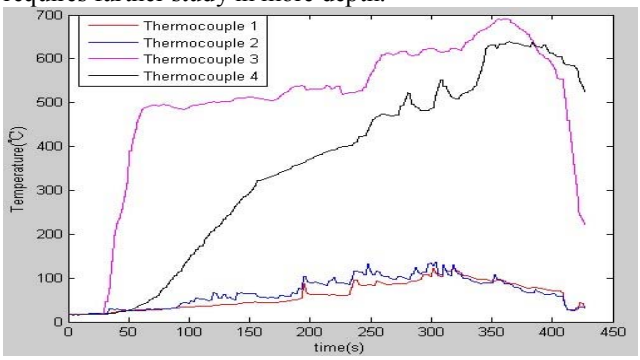

Figure 3. Temperature changing curve of the SDBS solution in concentration of 0.4%

C. *Water mist on fire suppressing experiment using chemical additives*

In this experiment, we choose NaCl, $NaHCO_3$ for the chemical additives. We choose three kinds of NaCl, $NaHCO_3$ solution in different status of concentration. The experimental results are shown in table 2 and table3.

From the experimental result we can conclude that the fire suppressing performance increases with the increasing of the concentration of NaCl, and when it reaches to a certain value, although the fire suppressing performance increased but it's obviously less than the past. If we considered from both the economic side and the fire suppressing performance side, when the concentration of NaCl is near to 2%, the cost performance could be the highest for the water mist. After the adding of $NaHCO_3$, with the increasing concentration of NaCl the fire suppressing performance improved obviously. But it almost doesn't change in the fire suppressing performance when the concentration of $NaHCO_3$ comes to 2%. If only take the fire suppressing performance into consideration, it's superior for the wood crib fire to add $NaHCO_3$ than NaCl.

Table 2 Fire suppressing experiment by water mist with NaCl

Concentration of NaCl	Nozzle pressure （MPa）	Precombustion time（Min）	Fire suppressing time（s）
0	4	7	78
1%	4	7	73
2%	4	7	49
5%	4	7	40

Table 3 Fire suppressing experiment by water mist with $NaHCO_3$

Concentration of $NaHCO_3$	Nozzle pressure （MPa）	Precombustion time（Min）	Fire suppressing time（s）
0	4	7	78
1%	4	7	52
2%	4	7	21
4%	4	7	20

D. *Water mist on fire suppressing experiment using composite additives*

A single additive suppressing performance is limited, especially when the combustion characteristic difference among different kinds of combustible are sharply, so it's necessary to research the fire suppressing performance of composite additives which are a consist of different types of additives. This experiment do a research aimed at the fire suppressing performance with three different types of composite additives which containing surfactant in concentration of 0.1%, 0.2%, and 0.3% respectively with the NaCl solution in concentration of 2%. The experimental results are shown as table 4. The curve belongs to 0.2% in concentration's solution which stand the relationship between the temperature in fire and their suppressing time are shown as figure 4.

Table 4 Experimental results of fire suppression by water mist containing composite additives

Con-centration of SDBS	Con-centration of NaCl	Nozzle pressure (MPa)	Precombustion time（Min）	Fire suppressing time（s）
0.1%	2%	4	7	15
0.2%	2%	4	7	9
0.3%	2%	4	7	9

The experimental results show that adding composite additives have more advantages than the one that adding single, according to the total costs, it's lower for the composite than the single added one while both of them could reach to the best suppressing performance. Generally, the mainly effect of SDBS additives is to reduce the surface tension of water, make it easier for water and fuel surface contact, thus the cooling efficiency improved. The main function of the NaCl additive is to capture free radicals in

fire, to terminate the chain reaction process of flame. For wood crib fire suppression, intensity of combustion can be obviously down by terminating the chain reaction process of flame, especially better for open fire. But a directly contaction with water will be the best when regard to the combusting of fixed carbon. So, the adoption of SDBS combined with NaCl as composite additive can obtain better fire suppressing performance. The costs of SDBS are much higher than NaCl, but when it comes to the composite one which can gain the best suppressing performance, the cost can only be half of the choice of using SDBS only.

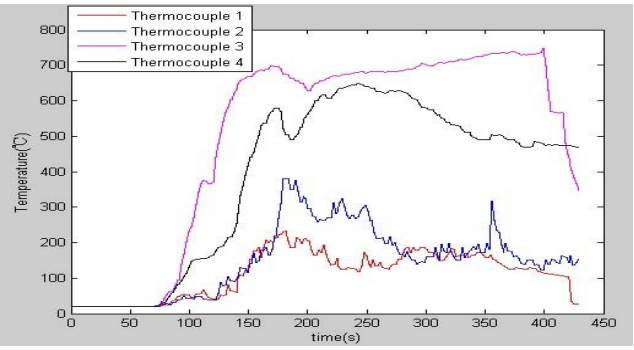

Figure 4. Temperature changing curve of the solution containing composite additives which comprised by 0.2%SDBS and 2%NaCl

V. CONCLUSIONS

According to the experimental results we come to the following conclusions:

The wood crib fire suppressing performance by water mist can be improved by adding additives, and the fire extinguishing efficiencies are so different among several of additives. When using the single additive, regardless of the price, the suppressing effect will be the best after the adding of SDBS additive. Using composite additive can achieve the best suppressing effect, and the total cost of additive is lower than the single added one. All this shows that there is an optimal concentration or the best concentration ratio exists for all the additives, of course it may be different between wood crib fire and other kinds of fire. So how to find the optimal concentration or the best concentration ratio of the additives using in the various fire suppressions is essential. Sometimes in the experiment, the fuel will be reburn, this indicates that the ability of suppressing a naked flame is well, but the control capabilities on fixed carbon combustion are inadequate. The phenomenon of temperature falling slowly is enough to explain this point. To avoid the phenomenon of reburn, we can come into a method of changing the parameters such as the particle size, the flow of water mist as well as prolong the applying time of the water mist. However, this problem remains to be studied further.

REFERENCES

[1] CONG Bei-hua, ZHOU Xiao-meng, LIAO Guang-xuan, "Improvement of water mist fire suppression performance with composite additives", journal of university of science and technology of china.Vol.36, No.1, Jan.2006. (in Chinese)

[2] Liao Yide, "Research on High Pressure Fine Water Mist Fire suppression System Key Problems and its Performance", Doctor Degree thesis. Huazhong University of Science and Technology, Wuhan, Hubei430074, P.R.China.May, 2008.(in Chinese)

[3] Deng Dong, "Research on fixed high pressure single-phase water mist fire suppression system", Doctor Degree thesis. Zhejiang University, China.2006(in Chinese)

[4] Chen Zhen, "Experimental Study on Fire Extinguishment of Water Mist Containing NaCl Additives", Master Degree thesis. Xian University of Science and Technology,China.January.2007.(in Chinese)

[5] Xu Jun, "Study on the interaction between water mist contained compound additives and kerosene pool fire", Master Degree thesis. Henan Polytechnic University,China.Octorber.2006.(in Chinese)

[6] KUANG Kai-qian, CONG Bei-hua, LIAO Guang-xuan, "Experimental Study on the Fire Suppression Effectiveness of Water Mist with Ferrous Chloride Additives", journal of FIRE SAFETY SCIENCE,Vol.14,No.1,Jan.2005.(in Chinese)

[7] Huichang Niu, "Suppression performance of water mist with additives", master Degree thesis. Shen Yang Aerospace University,China.January.2011.(in Chinese)

[8] YU Ming-gao, DUAN Yu-long, XU Jun, YU Shui-jun, JIA Hai-lin, Z UO Qiu-ling, "Research and discuss on additives of spray mist", journal of Fire Science and Technology of China, Vol 26,No.2,March.2007.(in Chinese)

[9] Niu Guo-qing, "Theoretical and experimental study of compartment fire suppressed by water mists", Doctor Degree thesis, Central South University,May.2007.(in Chinese)

[10] LIU Jiang-hong, LIAO Guang-xuan, LI Pei-de, LU Qiang," Experimental study on wood crib fire suppression with water mist", journal of Fire Science and Technology, Vol 23,No.1,January.2004.(in Chinese)

[11] YU Yong-gang, FENG Jin-li, LU Chun-yi, ZHOU Yan-huang, "Experimental Study on Interaction of Water Mist with Wood Crib Fire", journal of Nanjing University of Science and Technology,Vol.29,No.5,Oct.2005.(in Chinese)

[12] LIU Jiang-hong, LIAO Guang-xuan, LI Pei-de, Qin-jun," Experimental study on the solid pool fire extinction time affect by Water Mist", journal of the SCIENCE IN CHINA(Series E),Vol 33,No.3,March.2003.(in Chinese)

[13] Ji Huanle, Zhang Qingsong, Wu Binbin, Liang Tianshui," Research of the effect of the component proportion in the new water mist additive to extinguishing performance", journal of Engineering Science, Vol 14,No.11,2012.(in Chinese)

[14] LI Ding-qi, WU Qing, YU Ming-gao," Experiment Study on Evaluating Fire extinguishment capability by O2 Analysis in Fire Extinguishment Experiments of Water Mist Containing Additives", journal of SAFETY IN COAL MINES,March.2008.(in Chinese)

[15] NFPA 750, Standard on Water mist Fire Protection systems, 1996 Edition.

[16] G. Grant, J. Brenton, D. Drysdale. Fire suppression by water sprays. Progress in energy and combustion science, 2000, 26(2):79-130.