International Journal of Thermal Sciences 125 (2018) 44–51

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Preliminary study on fire protection of window glass by water mist curtain

Xishi Wang[a,*,1], Qiong Tan[a,b,1], Zhigang Wang[a], Xiangxiao Kong[a], Haiyong Cong[a]

[a] State Key Lab. of Fire Science, University of Science & Technology of China, Hefei 230026, China
[b] Operation and Monitoring Centre for Hefei Urban Safety & Security, Hefei 230601, China

ARTICLE INFO

Keywords:
Building fire
Water mist curtain
Radiant heat attenuation
Window glass

ABSTRACT

Glass may easily break during a fire that can significantly accelerate the enclosure fire development. Water mist, as an efficient fire suppression technique, has been used for fire protection of an object due to fire radiant heat attenuation. The main purpose of this work is to investigate the behavior of the window glass heated by a fire and protected by a water mist curtain (WMC). Float glass with a dimension of 600 × 600 × 6 mm^3 exposed to a 0.16 MW gas fire was tested. The WMC was generated by a single orifice nozzle with K-factor of 1.01 L/min/$MPa^{1/2}$. The initial time of glass breakage, the temperature difference of the glass pane and the heat flux penetrating through the glass were measured and compared. The time of the window glass pane maintaining its integrated structure under the protection of WMC extends to more than 600 s comparing to 150 s of that without the protection of WMC. More than 38.5% thermal radiation of the fire would be attenuated by the WMC with thickness of 0.075 m and operating pressure of 1.0 MPa. The WMC demonstrates a better cooling capacity that can protect the glass from breakage more effectively comparing to water film with same flow rate. It is also found that the delaying of the activation of the WMC system contributes little to the crack or fallout of the float glass. The results may be helpful for providing guidelines on keeping glass integration in building fire scenarios.

1. Introduction

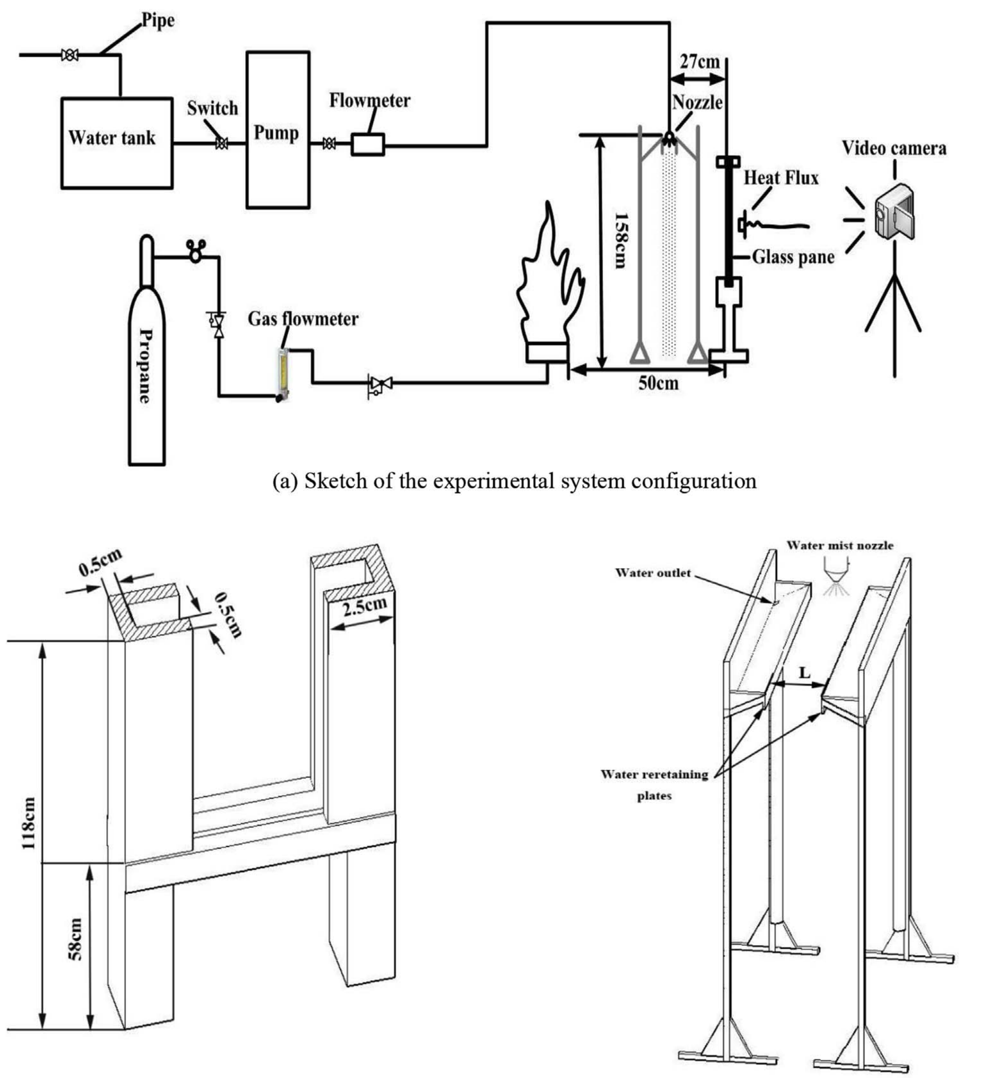
Window glazing is widely used for modern architectures, especially for high-rising buildings. However, some of them are easily damaged by an enclosure fire due to their intrinsic characteristic of brittleness. The sudden venting caused by falling down of glazing in an enclosure fire may provide a corridor for fresh air and an exit for hot fire gases, leading to the acceleration of fire spread and fire development in building [1,2].

To date, a large number of attempts have been made to improve the heat insulation of the glass pane in case of a fire with intensive heat radiation or heat convection [3–8]. Water is widely used for firefighting because of its simplicity, efficacy and adaptability to different types of fires. Window sprinklers are currently installed in some high-rise buildings to protect the glazing [9,10]. Kim et al. [3,4] investigated the protection of window glass pane from external fire exposure with sprinklers. They have summarized plenty of methods to protect glazing assemblies with dedicated sprinkler systems from compartment fire exposures and provide a design guide for practical application of the exterior window protecting sprinkler system. Wu et al. [5,6] conducted a series of full-scale experiments to investigate the heat resistance and the absorption of convection heat of glass panes incorporated with water film or sprinkler in a room fire. The results indicate that water film can restrain the surface temperature of the glass effectively in the initial stage of the fire, and even when the fire begins to burn intensely, the surface temperature of the glass can still be controlled around 100 °C. The effective heat resistance of the water film is better than that of the sprinkler system even if the flow rate of the former is smaller. Shao et al. [9] highlighted that the crack even fallout of the tempered glass exposed to fire would be accelerated when acting the water film at 250 °C. Shu et al. [11] studied the single-pane fire-resistant glass performance with sprinkler protection, and stated that the temperature of unexposed surface is below 50 °C and the thermal radiation flux at the side of single-pane fire-resistant glass with sprinkler is quite lower than those without sprinkler condition.

Water mist has been regarded as one of the most potential techniques for replacement of the chlorine- or bromine-based gaseous fire suppressants known as Halons, it also should has better performance for window glass protection. For instance, Zhu et al. [12] experimentally and numerically studied the thermal radiation attenuation from large fires by WMC with low and intermediate pressures. Their results show that the WMC has high thermal radiation attenuation efficiency, e.g., about 82.7% radiant heat flux could be attenuated by WMC with 2 MPa working pressure and flow rate of 13.3 L/min. Wang et al. [13] studied

* Corresponding author.
E-mail address: wxs@ustc.edu.cn (X. Wang).
[1] The authors contributed equally to this work and should be considered co-first authors.

https://doi.org/10.1016/j.ijthermalsci.2017.11.013
Received 18 August 2016; Received in revised form 30 September 2017; Accepted 15 November 2017



(a) Sketch of the experimental system configuration

(b) Sketch of the aluminum frame

(c) Sketch of the water retaining device

Fig. 1. Schematic diagram of the experimental apparatus.

the fire smoke control in channel by using WMC, the results indicate that the smoke particles and CO gas released by the fire could be reduced to a great extent, and the temperature of the protected zone could be effectively cooled down when the WMC system was applied.

However, there is few literature about retarding crack or fallout of window glass pane with WMC. In this study, the main goals are not only to evaluate capability of WMC on fire protection of window glass, as well as the comparison with water film, but also to investigate the effect of WMC activation time on window glass protection. Therefore, different thickness of WMC and different time to act the WMC system are employed for the tests and analysis. The results of this work may be useful for building fire safety guideline and the optimization of WMC system design for window glass protection.

2. Experimental apparatus and methods

Fig. 1(a) presents the sketch of the experimental setup. The experimental apparatus mainly consists of a gas pool fire, a WMC system, a temperature and radiant heat flux measurement system and the test model of window glass pane.

During the experimental tests, the window glass pane ($600 \times 600 \times 6$ mm^3) was installed by an aluminum frame with a distance of 500 mm away from the gas pool fire which was simulated via a 350×350 mm^2 square pan and propane was adopted as the fuel. The sketch of the aluminum frame is presented in Fig. 1 (b). The glass pane was not directly attached to the aluminum frame, a blank between the glass and the frame which was simply filled with refractory (glass cotton) to prevent the free extensions of the glass. To more similarly resemble real life scenario, the vertical distance from the glass pane to the bottom of the gas burner is 500 mm. In the experiment, the width of the covered region on each edge of the glass is about 20 mm.

As shown in Fig. 2, nine thermocouples were fixed on both of the exposed and unexposed surfaces of the glass pane, while four thermocouples were placed on the frame covered region of the glass pane to obtain the temperature history during the test. The thermocouples used in the experiment are K-type sheet thermocouples with 6×10 mm^2 sensing area and 0–1000 °C measurement range. As shown in Fig. 1(a), radiant heat flux was obtained by a MEDTHERM 64-10-20 heat flux meter with 0–50 kW/m^2 measurement range (produced by MEDTHERM Corporation), which was fixed 50 mm away from the unexposed surface along its centerline. A SONY HDR-PJ10E video camera was used to record the whole process of the experimental tests. In addition, a LaVision Particle Master system based on shadowgraphy technique was used for droplet size measurement, the details of this system can be seen elsewhere [13–15].

The WMC system includes a water tank, a flow-meter, a variable-frequency hydraulic pump, a single orifice water mist nozzle and stainless steel pipes. The maximum spray angle of the nozzle is 65°. The