Influence of Wind Speed and Direction on the Combustion Parameters of the Exposed XPS Insulation Wall

Lanfang Zheng\textsuperscript{1}, Liang Zhou\textsuperscript{2,*}, Xiangtao Jia\textsuperscript{3}, and Xiaokang Li\textsuperscript{1}

\textsuperscript{1}Fire Protection Engineering Department, China People’s Police University, 065000 Langfang, China
\textsuperscript{2}Department of Safety Science and Engineering, University of Science and Technology Beijing, 100083 Beijing, China
\textsuperscript{3}Gannan Detachment of Qiqihar Fire and Rescue Detachment, 161000 Heilongjiang Province, China

Abstract. Most of the fire accidents of exterior insulation in recent years started with the ignition of unprotected and exposed insulation materials. The fire spread on the thermal insulation layer will be affected by outdoor wind. In this paper, the influence of wind direction and wind speed on wall fire propagation characteristics was studied by carrying out medium sized experiments. The temperatures on the wall surface, radiation heat flux nearby, the infrared image and flame image were recorded during the tests with variation of wind direction and wind speed. It is found that with the increase of the angle between the wind direction and the wall, the surface temperature of the material, the radiation heat flux released decreases. This study results can provide valuable references for optimizing the fire safety design of exterior insulation layer.

1 Introduction

In recent years, severe exterior insulation fires occurred frequently in our country. According to statistics, 90% of exterior insulation fires occurred in recent years happened during the construction stage when the thermal insulation panels were completely or partly exposed to air.

Extruded polystyrene (XPS) adopted in this paper has low water absorption rate, good thermal insulation capability, strong pressure resistance, and is not easy to break or deform. It is one of the most widely used insulation materials in Chinese construction industry. Heat transfer process is very complex in the process of wall fire spreading. There is heat conduction between the insulation material and the base wall; the heat radiation will be produced during the burning process; the floating fire plume will heat the unburned material above, and the melting and dripping behavior will occur during the vertical fire spread because the XPS is a thermoplastic material. All these physicochemical changes make the combustion process more complicated. Therefore, compared with numerical simulation, theoretical analysis and other research approaches, the experimental research is the most reliable and effective way. Through the study of experimental data and flame images, the combustion characteristics and fire spread behavior of the exterior insulation materials can be found out.
2 Experiments

2.1 Experimental platform

The main experimental platform is a frame made of steel with a height of 3 m and a width of 1.5 m. A pool plate with a width of 0.6 m, a length of 2 m is welded under the frame to accommodate the molten drops produced during burning.

2.2 Wind-generating device

The wind generating device is composed of three parts: a blower, a variable frequency controller and wind outlets. In order to make the speed of wind coming from the outlets to be evenly distributed, 6 blowers were fixed inside and kept in the same distance to the outlets. Besides, three layers of fine metal meshes were installed before the wind come to the exit. The wind speed of the generator was adjusted and stabilized by using the frequency conversion controller.

Figure 1. Photo of the wind generation device.

According to the preliminary experiments, when the wind speed is too high, the fire will be extinguished due to the insufficient combustion at the early stage of burning. So two wind speeds adopted in this study was designed as 1.5m/s and 2.5m/s. In addition, the influence of wind direction were explored by varying the angle between the wind and the platform to be 0°, 30°, 60° and 90° respectively to simulate different outdoor wind directions as shown in Fig 2.
2.3 Ignition source

In order to simulate actual fire scenarios, butane gas torch with flame temperature 1200–1300 °C located at the center of bottom edge was used to ignite the insulation panel and moved away after 8 s of application.

3 Experimental results

The flame spread behavior of wall fire are not only affected by the properties of the insulation material, but also influenced by the exterior temperature, humidity, tilt angle and other factors. Among all the factors, the outdoor wind may have the largest impact on the shape and tilt of flame, heat transfer processes as well as the growth and the spread of fire.

3.1 Temperature

It can be seen from the experimental data that under the same wind speed condition, the influence of wind direction on the measured temperatures has a certain rule. Figure 2 (a) shows the temperature curve of M3 under different wind directions with the wind speed fixed at 1.5 m/s. As can be seen from the figure, when the wind direction increases from 0° to 60°, the peak temperature of M3 temperature gradually decreases and the time to reach the peak temperature is shortened. This is because the increase of the angle between wind direction and panel enlarges the flame tilt and decreases the radiant heat flow rate leading to lower measured temperature. When the angle between the wind direction and the panel is 90°, the peak temperature of M3 is the lowest, and the time to reach the peak temperature is the largest.

Fig. 3 (b) gives a comparison of the temperature curves at M3 under different wind directions with the wind speed of 2.5 m/s. It can be seen from the figure that when the wind direction increases from 0° to 90°, the peak temperature of M3 gradually decreases and the time to the peak temperature gradually grows longer. In comparison with Fig. 3 (a), when
the angle between wind direction and the wall is 90°, the trend are inconsistent under the two different wind speeds.

![Graph](image1)

(a) Under wind speed of 1.5m/s  (b) Under wind speed of 2.5m/s

**Figure 3.** Temperature change of M3 point under different wind conditions.

According to the above measured temperature of M3, when the angle between wind direction and the wall increases from 0° to 90°, the temperature peak at this point gradually decreases. As the angle increases, temperature on the wall of XPS panel decreases. When the wind speed is 1.5m/s, as the wind angle increases from 0° to 60°, and the time to peak temperature gradually shortens, however the time to peak temperature is the longest when the angle between wind direction and the wall is 90°. While when the wind speed is 2.5m/s, the time to peak temperature gradually shortens as the wind angle increases from 0° to 90°.

### 3.2 Radiant heat flux

As shown in Fig. 4, under the same wind speed, when the angle between wind direction and the wall increases from 0° to 60°, both the peak value and the total radiant heat flux decrease, and the peak value of radiant heat flux appears earlier for the two different wind speeds. However when the angle between wind direction and the wall increases from 60° to 90°, there trends are different for the two wind speeds. When the angle between the wind direction and the wall remains the same, the peak value of radiant heat flux curve increases and the time to the peak value shortens when the wind speed is lower.

![Graph](image2)

(a) Under wind speed of 1.5m/s  (b) Under wind speed of 2.5m/s

**Figure 4.** Influence of wind direction on the measured radiant heat flux.
4 Summarization

In order to better improve the fire safety performance of the exterior insulation system during the exposed stage of construction, medium sized experiments were carried out to simulate the exterior wall fire spread over the insulation layer with manually generated wind. The influences of wind conditions on the wall fire spread were investigated. When the angle between wind direction and the wall increases from 0° to 60°, the measured peak temperature and radiant heat flux released decrease, and the time to reach to peak temperature and radiant heat flux shortens. When the wind speed increases from 1.5m/s to 2.5m/s, both the peak temperature and the peak radiant heat flux released decrease, and the time to reaches the peaks grows longer.

According to the above experimental results, it can be seen that the fire growth and flame spread, of the insulation layer will be obviously influenced by wind speed and wind direction. Therefore, not only the flammability of the insulation material, but also the outdoor wind impact should be considered during the fire safety design of insulation system.

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