Research and Analysis on Fire Simulation of Underground Pipe Gallery Based on Pyrosim Software

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Abstract. In order to analyze the influence of the abrupt section of the underground pipe gallery on the spread of smoke, this paper uses fire simulation software to establish a numerical model to study and analyze the pipe gallery with abrupt sections. The simulation results show that under the condition of working condition 2, the temperature of the pipe gallery increases and then decreases. The highest temperature is at 182s, and the highest temperature is 698.51 ℃; in the sudden change section, the smoke spreading rate decreases, and the smoke peak The surface presents a “convex” shape; due to the thermal effect pressure difference and the mechanical wind pressure difference, when the wind speed in the pipe gallery is 0-50s, the wind speed changes greatly; when the inlet wind speed is 1m/s, the wind speed in the pipe gallery will eventually Tend to be 2.5m/s.

1. Introduction

With the changes in urban management pattern and spatial structure, urban underground space has the advantages of saving land, improving road landscape, and improving power supply safety compared with traditional power and communication overhead lines. Its advantages are used by urban managers in super-large cities and large cities. Favor, especially the construction and utilization of underground comprehensive pipe corridors. However, the shortcomings of underground comprehensive pipeline gallery fire accidents such as suddenness, uncertainty, large impact range, and difficulty in rescue have always attracted people's attention. Therefore, underground comprehensive pipeline gallery fires have become the focus and hotspot of domestic fire research. Domestic and foreign scholars have studied underground pipe gallery fires in terms of fire source location, pipe gallery shape, fire source intensity, etc., and proposed corresponding control measures; for example, Zhai Yue [1-2] studied the influence of different fire sources on the evacuation of personnel; Zhuang Yulin [3] studied and analyzed the law of fire smoke spread in L-shaped pipe gallery. Zong Yanyan [4] used PyroSim fire software to simulate the fire accident during construction; KaiLiang [5] used FDS to analyze the spread of fire smoke in the T-shaped pipe gallery.

To sum up, the fire research of the pipe gallery ignores the influence of the widened section of the underground cable pipe gallery on the spread of smoke. Therefore, this paper is based on the pyosim fire simulation software to carry out the fire smoke of the cable ignited fire scene in the cable pipe gallery project. The simulation analysis obtains the internal temperature distribution, smoke concentration, visibility and wind speed in the pipe gallery under different working conditions, which provides a certain reference for the actual fire extinguishing of the underground cable pipe corridor.
2. Model establishment and working conditions

2.1. Working condition setting
In this paper, a certain section of the pipe gallery project in Xi’an is selected as the simulation object. This simulation selects an interval K0+715~K0+915 of the underground pipe gallery with a total length of 200m. The project size of the pipe gallery is 200m×1.8m×2m in length×width×height, and the length×width×height of the widened section of the pipe gallery is 6m×3m×2 m, as shown in figure 1 and figure 2. The simulation time is 300 s. Ventilation methods are divided into two types: natural ventilation and mechanical ventilation; the wind speed of mechanical ventilation is 0, 0.5 and 1m/s; due to the layout of the cable line material in the pipe gallery, the fire source intensity is selected to be 1.5MW and 3.0MW. Other relevant parameters of the simulation model are shown in table 1. The parameters of each working condition of the simulation test are shown in table 2.

![Figure 1. Sectional drawing of underground pipe gallery.](image)

![Figure 2. Sectional view of the widened section of the underground pipe gallery.](image)

| Conditions | Position of ignition point | Temperature(℃) | Pressure(Pa) | Gravity acceleration(m/s) |
|------------|---------------------------|----------------|--------------|---------------------------|
| Parameter value | center | 20 | 1.013 25×10⁵ | -9.81 |

| Working condition | Wind speed(m/s) | Fire point location | Fire source intensity(MW) |
|-------------------|-----------------|---------------------|---------------------------|
| 1                 | 0               | center              | 1.5                       |
| 2                 | 0               | center              | 3.0                       |
| 1-1               | 0.5             | center              | 1.5                       |
| 2-1               | 0.5             | center              | 3.0                       |
| 1-2               | 1               | center              | 1.5                       |
| 2-2               | 1               | center              | 3.0                       |

2.2. Simulation observation point setting
In order to analyze the spread law of fire smoke in underground pipe gallery, temperature, wind speed, smoke concentration and visibility measurement points and slices were set in the experimental model. According to the "Report on the Status of Nutrition and Chronic Diseases of Chinese Residents (2020)", the average height of Chinese adult men is 169.7 cm. Monitoring points are set at the underground pipe gallery at 1.7 m from the ground and every 10 m to measure various parameter values.
2.3. Grid size setting
The network size of FDS fire simulation software is affected by the fire characteristic diameter $D^*$ [6-7]. In order to make the simulation results reflect the actual situation, calculate the fire characteristic diameter $D^*$ according to formula (1), and combine the grid size $d=0.1D^*$ and $d=0.2D^*$. 1.5MW and 3.0MW use grid divisions of $0.5m\times 0.5m\times 0.5m$ and $0.8m\times 0.8m\times 0.8m$, respectively.

3. Analysis of simulation results
After a fire occurs in an underground pipe gallery, the smoke and high temperature generated by the fire are the biggest impact on the construction personnel. Therefore, it is necessary to study the flue gas temperature distribution, visibility and wind speed of the pipe gallery; the wind speed affects the smoke spreading time in the pipe gallery, namely Evacuation time is available for construction personnel.

3.1. Temperature analysis in underground pipe gallery
Through the analysis of the temperature galvanic point above the ignition point under the conditions of working condition 2, working condition 1, and working condition 2-1, the influence of wind speed, heat source intensity and ignition point distance on the dynamic distribution of temperature inside the underground pipe gallery is studied, as shown in figure 3. As shown, the wind speed of the air inlet of working condition 2 is 0m/s.

It can be seen from figure 3 that the temperature of the pipe gallery changes with time under the condition of working condition 2, showing a first increase and then a decrease. The highest temperature is at 182s. Due to the oxygen concentration in the pipe gallery, the heat source intensity decreases, and the temperature reaches the peak after the temperature reaches the peak. The highest temperature is 698.51°C; by comparing working condition 2 and working condition 2-1, it is found that under the influence of wind speed, the temperature accumulation of pipe gallery is reduced; working condition 2-1 does not show a trend of temperature decrease, and the temperature change rate gradually decreases. By analyzing the temperature changes of working condition 2 and working condition 1, the greater the intensity of the heat source at the ignition point, the higher the temperature inside the pipe gallery, but the temperature reduction trend of working condition 1 did not appear. The temperature in the pipe gallery gradually increases, and the temperature growth rate decreases. The farther away from the ignition point, the later the temperature starts to change, and the smaller the highest temperature point, the lower the temperature change rate.

Under the condition of working condition 2, the temperature of the pipe gallery began to decrease after 182s, mainly due to the decrease of oxygen content in the pipe gallery, which led to the decrease of the fire source intensity, and finally the temperature of the pipe gallery spread from the ignition point to both sides. Comparing working condition 2 and working condition 2-1, when a fire occurs, the ventilator cannot reduce the flue gas and temperature inside the pipe gallery, and the flue gas can only be discharged through natural vents. If the ventilators are turned on, fresh air may enter the corridor and produce combustion-supporting effects, making the fire situation more difficult to control. It can be seen from the real-time graph of fire simulation that after 182s, the highest temperature spreads to both sides of the fire point, as shown in figure 3.

![Figure 3. Working condition 2 temperature-time dynamic change graph.](image-url)
3.2. Smoke visibility analysis
Because the viscous force of the wall surface of the pipe gallery forms a retarding effect on the flue gas, the front peak of the flue gas presents a "convex" shape at the initial stage of the smoke spread; as the smoke spreads, the pipe gallery avoids viscous force when reaching a certain distance The effect on the flue gas gradually weakens, and the flue gas front takes a "concave" shape; the farther away from the ignition point and the sudden change of the pipe gallery, the lower the avoidance of the pipe gallery, the lower the flue gas peak surface velocity of the pipe gallery; The sudden change section causes the smoke peak surface to be compressed and stretched, and the smoke spread rate of the sudden change section decreases, and the smoke peak surface presents a "convex" shape. As shown in figure 4, the flue gas spreading diagram at different time periods of the pipe gallery.
By comparing working condition 1-1 and working condition 1-2, under the same fire source intensity, as the inlet wind speed increases, the length of the flue gas counterflow decreases. When the inlet wind speed is 0.5m/s, the flue gas reverses Spread 35 meters, as shown in figure 5(a); when the wind speed is 1m/s, the smoke does not spread in the reverse direction, as shown in figure 5(b).

![Figure 4. The influence of the sudden change on the spread of concentration.](image)

![Figure 5. Smoke spread from pipe gallery.](image)

3.3. Analysis of wind speed in underground pipe gallery
Through the comparative analysis of the wind speed galvanic couple point (V19) under the conditions of working condition 2, working condition 2-1, working condition 2-2 and working condition 2-3, the influence of the wind speed of the air inlet on the wind speed in the pipe gallery is studied, such as Shown in figure 6.

![Figure 6. Speed change in the pipe gallery with time.](image)

![Figure 7. Speed change in the pipe gallery with time.](image)

It can be seen from figure 6, that when the wind speed in the pipe gallery is 0-50s, the wind speed changes greatly; but after 50s, the wind speed change in the pipe gallery is relatively slow; with the increase of the wind speed at the air inlet, the final average wind speed in the pipe gallery also It increases
with it and is relatively stable; when the inlet wind speed is 1m/s, it is relatively stable; due to the initial combustion of the pipe gallery, the heat release rate fluctuates greatly, which causes the pressure difference caused by the thermal effect of the pipe gallery to fluctuate, resulting in the initial pipe gallery Wind speed fluctuates greatly. The pressure difference generated by the thermal effect, the pressure difference between the wind pressures, and the combustion promotes the airflow to rise, etc., which cause the average wind speed in the pipe gallery to increase. As the inlet wind speed increases, the mechanical wind pressure increases. When the pressure difference between the mechanical wind pressure and the thermal effect pressure decreases, the wind speed in the pipe gallery gradually stabilizes. Under the conditions of mechanical wind speed of 1m/s and different heat source strengths, the greater the intensity of the heat source at the ignition point, the greater the average wind speed of the final pipe gallery, as shown in figure 7. The average wind speed of the pipe gallery under the conditions of Working Condition 2-2 and Working Condition 1-2 is 2.5m /s and 2.2m/s.

4. Summary
By analyzing the influence of underground pipe gallery fire source power and wind speed on smoke spread and visibility, the following conclusions are drawn:

(1) Under the condition of working condition 2, the temperature of the pipe gallery changes with time, showing first rise and then decrease, the highest temperature is at 182s, and the highest temperature is 698.51℃; compare working condition 2 and working condition 2-1, if the ventilation is turned on The air may enter the corridor and produce combustion-supporting effect, making the fire situation more difficult to control.

(2) In the sudden change section, the smoke spread rate decreases, and the smoke peak surface presents a "convex" shape; under the same fire source intensity, as the inlet wind speed increases, the length of the smoke counterflow decreases, when the wind speed is 1m/ At s, the smoke does not spread in the reverse direction.

(3) Due to the thermal effect pressure difference and the mechanical wind pressure difference, the wind speed changes greatly from 0 to 50s; but after 50s, the wind speed change in the pipe gallery relatively slows down. When the inlet wind speed is 1m/s, the wind speed in the pipe gallery finally stabilizes at 2.5m/s.

5. References
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