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A Review on the Application of Simulation Technology in Subway Ventilation System

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Abstract: *This paper presents the characteristics and research methods of the subway environment, as well as application cases in three scenarios: natural ventilation, screen door leakage and air conditioning ventilation in subway stations. These cases show that simulation can evaluate and optimize subway ventilation design solutions, providing important engineering applications for the feasibility and reliability of subway ventilation systems.*
Keywords Adopts *Subway station ventilation design; Ventilation method; Environmental characteristics of subway stations; Simulation Technology*

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I. Introduction

In recent years, the subway has become one of the means of transportation that people often take to travel. The subway project is a relatively closed underground project, and the temperature, humidity, concentration of harmful substances and air flow rate in the subway station must be controlled to provide a suitable environment for passengers and to ensure the safety of passengers in case of emergency, however, the design process often makes the design air volume too large resulting in energy waste and high operating costs. However, in the design process, the design air volume is often too large, resulting in energy waste and high operating costs. For this reason, it is necessary to determine an energy-efficient and reasonable environmental control system plan and conduct environmental control simulation calculation. Simulation technology is a computer numerical calculation of the original continuous field of physical quantities in the time and space domain replaced by a series of finite set of discrete points of the variable values, through a certain principle and way to establish a set of algebraic equations about the relationship between the field variables at these discrete points, and then to find the approximate value of the field variables and display through the image. Because of many irreplaceable advantages, it has been widely used in the design of subway station ventilation.

II. Characteristics and research methods of subway station environment

2.1 Characteristics of the subway station environment

Subway stations are generally located in the underground space of more than ten meters, and their changing characteristics have significant differences from those of above-ground buildings, which are manifested in the following four aspects [1].

(1) Subway stations have a relatively closed space and are basically isolated from the outside world except for a few parts such as entrances and exits. The internal air temperature of subway stations is mainly regulated by the station ventilation and air conditioning system to ensure the comfort of passengers.

(2) Trains, equipment and passengers release a lot of heat, which, if not discharged in time, will raise the temperature of stations and inter-district tunnels and affect the riding environment.

(3) The "piston effect" is generated when trains run in inter-district tunnels. If the design is not reasonable, it will interfere with the airflow organization of the station, which will reduce the comfort of passengers and affect the load of the station.

(4) When an accident occurs, especially a fire, the environment will deteriorate, making it difficult to rescue, and effective emergency measures must be taken.

To sum up, the main problems in the subway environment consist of three parts: 1.increase in ambient temperature;2.decrease in air quality;3.rapid changes in wind speed and pressure. Therefore, air quality, temperature and pressure transients are the three main problems of subway environment control [2].

2.2 Research Methodology of Subway Station Environment

At present, the method for the metro station environment mainly uses experimental measurements. The advantage of this method is that it can obtain first-hand real and credible data to provide a direct basis for metro environment design, but the experimental measurement is costly, takes a long time to test, is inefficient, and is constrained by many objective conditions such as model size, flow field disturbance and measurement accuracy, etc[3]. The comparison with simulation technology methods is shown in Table 1.

Table 1. Comparison of experimental measurement methods and numerical simulation methods

Method	Experimental measurement method	Simulation simulation method
Advantage	1)More accurate data； 2)As a basis for the design of the metro environment.	1)Multi-working condition testing; 2)Specific numerical reports; 3)Intuitive visual images.
Disadvantage	1)long and inefficient testing time; 2)It is limited by multiple objective conditions.	1)The reliability of numerical simulation; needs constant verification and correction.

3.Progress in the application of simulation and simulation technology in metro ventilation design

The application of simulation and simulation technology in subway ventilation system is mainly divided into: simulation study of natural ventilation in subway station, simulation study of air leakage in subway screen door, simulation study of air conditioning ventilation in subway.

3.1 Simulation study of natural ventilation in subway stations

LiuYanan [4] investigated the natural ventilation ventilation of the horizontal entrance of a typical metro station based on numerical simulation and experiments. Figure 1 below shows a model of a subway station with a dimensional scale of 1:10.

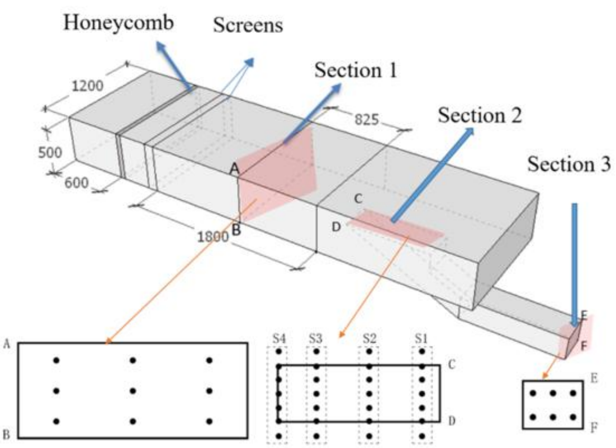


Figure 1. Subway station model (scale 1:10)

The effect of different parameters on the airflow at the entrance of the metro station is simulated by the RNG model and the existing real measurements The model was validated, and the comparison is shown in Figure 2.

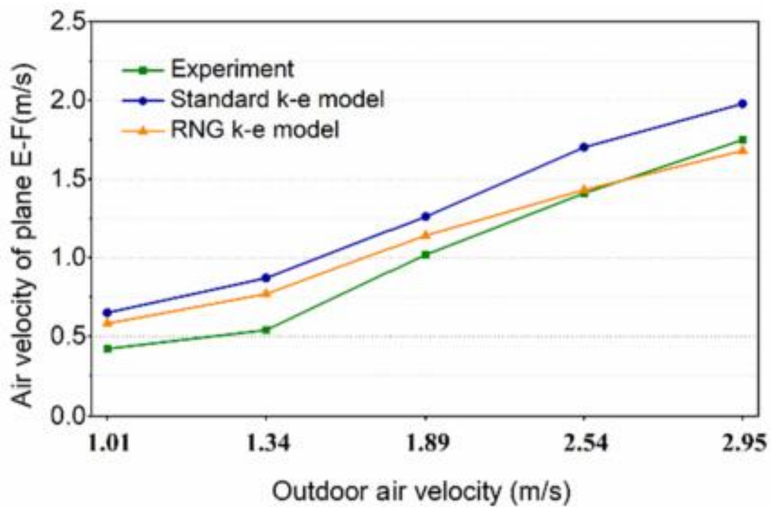


Figure 2. Comparison of measured and simulated results

As shown in Figure 3, comparing the pressure distribution of shelters of different lengths and heights, as well as the pressure distribution of horizontal openings in this paper, the results show that increasing the height of the shelter can effectively increase the percentage of positive pressure area over the horizontal opening, while increasing the length of the shelter will significantly increase the turbulence in the opening.

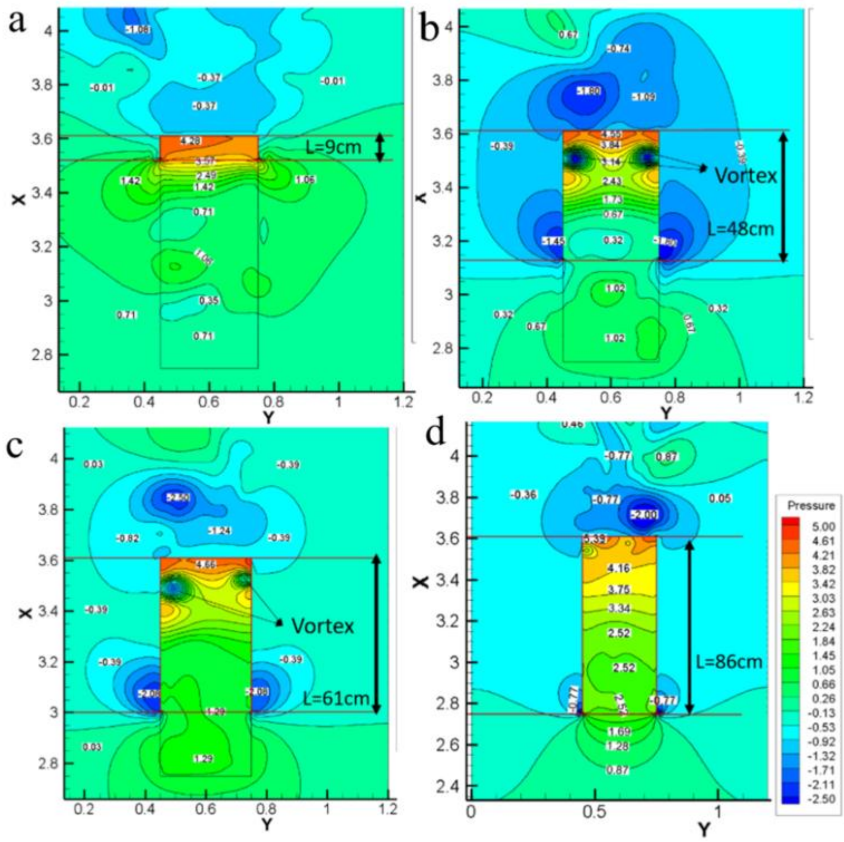


Figure 3. Pressure distribution for bunkers of different lengths and heights

As shown in Figure 4, finally this paper investigates the interaction between the internal and external flows by changing the resistance of the subway station, and the pressure coefficient of the inlet differs when the resistance of the internal flow is changed. Therefore, the pressure coefficient of the entrance is not only influenced by the outdoor environment, but also by the internal flow.

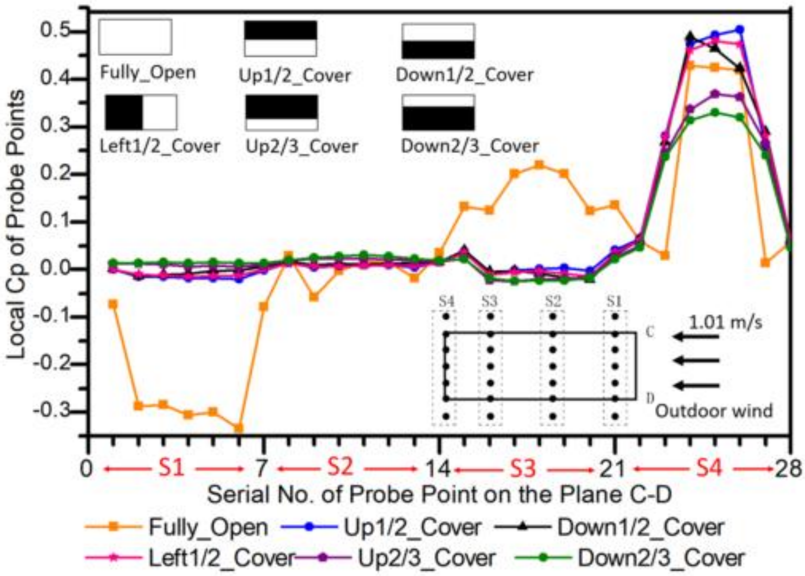


Figure 4. Pressure coefficient at the inlet for different values of internal flow resistance

HuYuxiang [5] takes the No. 1 entrance of Shapingba Station, Line 1 of Chongqing Metro as the actual physical model. In this paper, the effect of wind pressure on flat-entry subway entrances and exits is studied by using simulation, and the change of wind pressure and wind pressure coefficient between closed and unclosed subway entrances is compared, and it is found that the wind pressure and wind pressure coefficient in the above two cases are different. In addition, the effect of wind speed on wind pressure coefficient was also studied, and it was concluded that the trend of wind pressure coefficient with wind speed for closed and unclosed entrances and exits is not the same.

LiuKai [6] applies the finite volume method based on the incompressible fluid N-S equation and k-3 turbulence model theory to numerically simulate the thermal environment inside a double-island underground station with natural ventilation. Based on the above simulation analysis of the natural ventilation of the double-island underground station without shielded doors, it can be seen that when the trains stop at the outer tracks of the two platforms, the temperature inside the platform is the highest and the thermal environment is poor, with the increase of the number of trains on the middle track, the thermal driving force effect is enhanced and the air at both ends of the tunnel and the ground easily flows in from the tunnel openings at both ends, which makes the air flow rate inside the station increase and effectively reduces the temperature in the platform area. Therefore when two trains stop at the outside of the two platforms, it can be used as the most unfavorable design condition for naturally ventilated double-island underground station.

3.2 Simulation study of air leakage through screen doors of subway stations

Tao Haitao[7] used simulation to simulate the dynamic grid generation technology so that the grid can be adjusted continuously with the train movement in the tunnel, and simulated to get the air leakage when the screen door is opened, and concluded that the air flowing into the platform area in the tunnel is 23.05 m^3/s, and the air flowing into the tunnel in the platform area is 25.43 m^3/s.

Qi Weiyang[8] used simulation software to realize four processes of train uniformity, deceleration, standstill and acceleration by UDF compilation, and concluded that the average flow rate into the platform in the tunnel was 0.88 m3/s and the average flow rate into the tunnel in the platform was 10.03 m3/s.

Zhang Hong[9] used STESS combined with CFD simulation to calculate a typical island station platform.The air leakage from the screen door is 16.5 m^3/s, and the direction flows into the tunnel from the platform, the closer the air leakage is to the front of the car, the overall air leakage from the two screen doors corresponding to the rear of the car is from the tunnel into the platform.

Wang Dijun[10] used SES simulation software combined with CFD simulation to study the air leakage when the screen doors are opened, and concluded that the wind flow from the tunnel into the platform area is 16.30 m^3/s, and the wind flow from the platform area into the tunnel is 41.84 m3/s.

Zhao Quanchao[11] used SES simulation software combined with CFD simulation to obtain the conclusion that the average air leakage flowing to the tunnel during the opening of the screen door is 25.08 m^3/s and the average air leakage flowing to the platform is 21.87 m^3/s.

3.3 Simulation study of air conditioning and ventilation in subway stations

Yi Zheng[12] combines the research of piston air shaft system in underground stations of existing lines of Shanghai rail transit with three research methods, including field measurements, SES and CFD, to explore the intrinsic law of piston air shaft air exchange efficiency with air shaft setting and vehicle condition. The field measurements provide important boundary conditions and effective verification for numerical simulation; SES, as a professional rail transit loop control simulation software, facilitates the setting and adjustment of working conditions; CFD focuses on the study of velocity and pressure changes in the three-dimensional direction of the piston air shaft system.

Yuan Fengdong[13][14] simulated and analyzed the airflow of air conditioning in the side and island platforms of the subway, and the specific models of the side and island platforms are shown in Figure 5(a),(b).

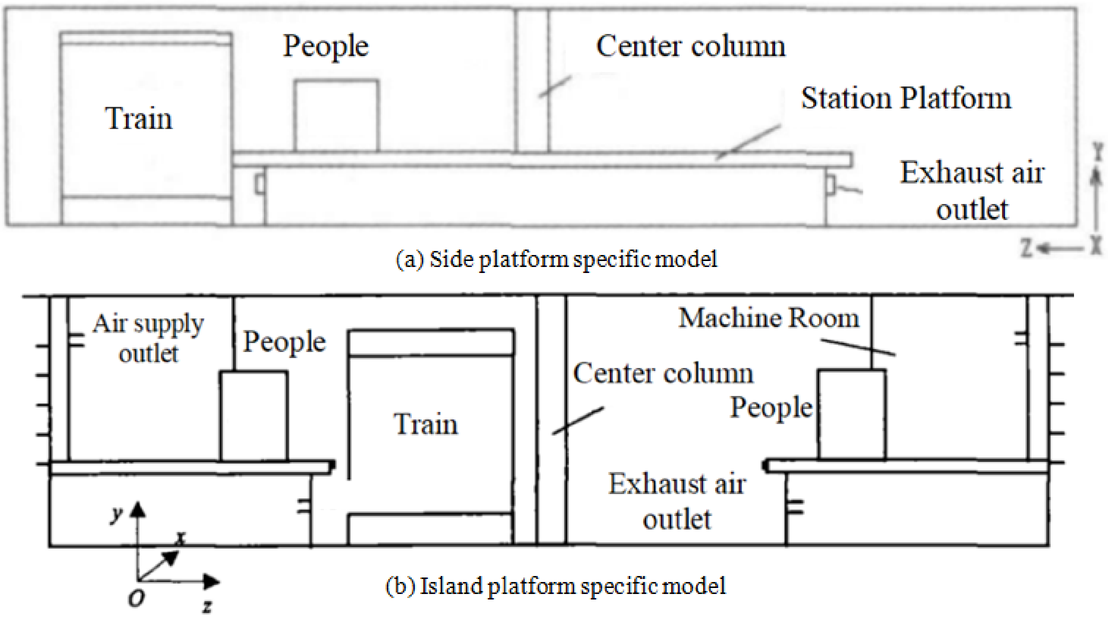


Figure 5. Diagram of different types of subway stations

In this paper, the boundary conditions are set according to the measured heat and humidity loads of the station platform, and the simulation results of the temperature field match with the measured values, and the results are shown in Figs. 6 and 7. This shows that the simulation analysis using the standard turbulence model can simulate and predict the temperature field of the subway platform more accurately, which provides a basis for the airflow organization design of the air conditioning system.

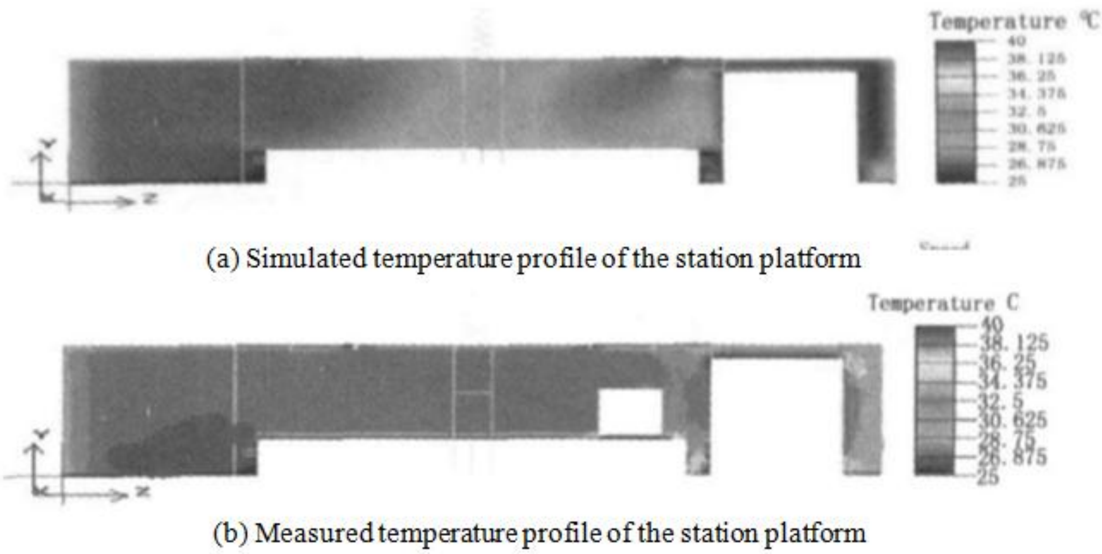
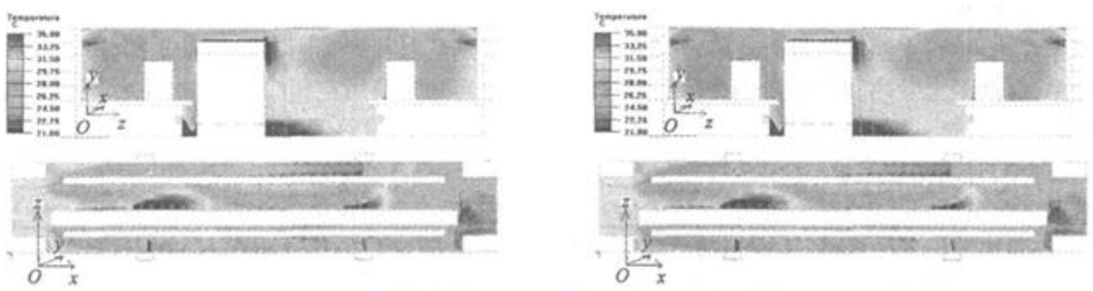
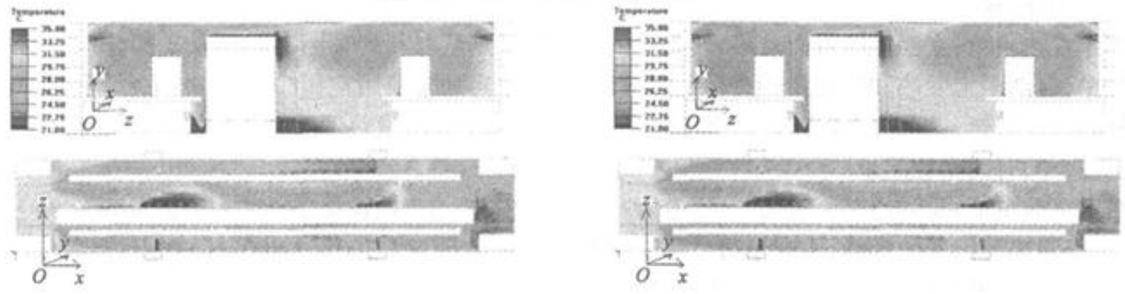


Figure 6. Comparison of simulated and measured results of island platform temperature



(a) Station simulated temperature



(b) Station measured temperature

Figure 7. Comparison of simulated and measured results of side platform temperature

IV. Conclusions

The above simulation study shows that the simulation can evaluate and optimize the feasibility and reliability of ventilation design schemes, especially natural ventilation, screen door leakage and air conditioning ventilation in metro stations, providing important engineering applications.

(1) The numerical simulation method (CFD) can be well used to predict and analyze the airflow organization of natural ventilation, screen doors and air conditioning systems in complex underground stations, and play a role in optimizing the design of air conditioning and ventilation system schemes, thus providing a basis for designing a reasonable airflow organization and improving the indoor comfort of personnel.

(2) The analysis efficiency and analysis accuracy of the simulation mainly depend on the value of the boundary conditions. When using simulation, the changes of passenger flow in subway stations and the changes of equipment lighting at any time are usually ignored, and the boundary conditions are set at constant values.

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