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Analysis of Train Safety Marking Settings Based on Bernoulli's Principle

Yaofeng Han, Heyu Qin, Yuting Wang, Changyou Cai*
Liaoning University of Science and Technology, Liaoning Anshan 114000

Abstract: With the process of urbanization and the rapid development of China's railways, the safety of passengers on the platform has received widespread attention. The purpose of this paper is to study the "suction" or "thrust" caused by trains and subways when passing through the platform through mathematical modeling, and to further analyze the basis for the setting of safety markings, so as to put forward suggestions to ensure the safety of railway platforms. In order to solve this complex problem, a theoretical model based on Bernoulli's principle is established to quantitatively describe the "suction" or "thrust" caused by the air pressure change caused by the operation of trains and subways to the platform passengers, and then the safety factor is introduced to consider passengers of different heights and weights. Then, the factors affecting the safety distance of the railway platform are found, the influence of various factors on the safety marking setting of the railway platform is analyzed, and some suggestions are provided according to these factors to ensure the safety of the railway platform, and the system optimization method is used to form a comprehensive understanding of it and make improvements. In summary, by comprehensively considering multiple factors such as train running speed, platform design parameters, passenger density and safety standards, a series of suggestions to improve the safety of railway platforms can be put forward to ensure the safe travel of passengers.

Keywords: Bernoulli's principle; Fluid mechanics; Safety marking; Platform safety

Introduce:

The China high-speed railway has made remarkable achievements after operations[1].In recent years, with the rapid development of China's railways, the transportation capacity of railways as the main artery of the national economy has been significantly enhanced, and the passenger and freight transportation capacity of railways has been significantly improved. In the modern urban transportation system, high-speed rail and subway, as a relatively efficient and convenient mode of transportation, with the deepening of the national economy and the leapfrog development of railways, the running speed, density and load of trains continue to increase.The safety of their operation is of paramount importance to passengers as well as railway managers[2]. As the most basic unit, the railway station plays an important role in the transportation of personnel and cargo resources, and the railway stations are all over the country, and thetotal amount is huge. The safety management of railway stations is very important because it protects the entire railway so that it can operate smoothly. As of now, railway accidents continue to occur, resulting in varying degrees of loss of life and property, especially when the high-speed rail and subway enter the station and pass through the platform, because the high-speed rail and subway will drive the nearby air to move at high speed.

1. Apply Bernoulli's equation

To study this, it is necessary to build a mathematical model based on fluid dynamics to calculate the magnitude of the "suction" or "thrust" on passengers on the platform when high-speed trains and subways pass through the platform at full speed, and the high-speed train will drive the air on both sides of the carriage to flow rapidly. According to Bernoulli's equation, the closer you get to the train, the greater the air velocity, and the human body will feel a force pushing the human body towards the train, which shows that its risk factor is extremely high. According to the explanation of Bernoulli's principle, the air pressure in the area with higher flow velocity is relatively low, and the air pressure in the area with lower flow velocity is relatively high, the air velocity of the passengers on the platform facing the train side is small, and the air flow velocity behind is small and the air pressure is large, at this time, the passengers on the platform will be affected by the air pressure difference between the front and the high, the closer the passengers are to the train and the faster the train speed, the greater the pressure difference between the person and the train, which will lead to a force that pushes from the high pressure area behind to the low pressure area in front of the body, that is, “suction” or “thrust”. If a passenger on the platform stands outside the safety markings in accordance with the regulations, this force will not cause the passenger to tip forward.

Barometric pressure differential calculation：

$$\Delta p = \frac{1}{2}\rho v^2$$

The area of the human body under force：

$$S = hw$$

Bernoulli's principle shows that for an ideal fluid, the pressure will be lower where the velocity is higher and the pressure will be higher where the flow velocity is smaller. Therefore, it can be expressed by Bernoulli's equation：

$$P + \frac{1}{2}\rho v^2 + \rho gh = cons\tan t$$

In this model, it is also necessary to comprehensively consider the influence of the wind force Fs and the friction force Ff between the passenger and the platform, and the wind force can be approximately regarded as the product of the air pressure difference and the area of the human body facing the wind direction：

$$F_s = \Delta PS$$

frictional force:

$$F_f = \mu mg$$

A simple exponential decay model is used to describe the change in wind speed over distance：

$$v(d) = v_0 e^{-kd}$$

Bernoulli's principle is often formulated as:：

$$P + \frac{1}{2}\rho v^2 + \rho gh = cons\tan t$$

Assuming that the air velocity in front of and behind the waiting passengers is v1 and v2 respectively when the train is passing at full speed, then we can express the air pressure difference as ：

$$\Delta p = \frac{1}{2}\rho\left({v_2}^2 - {v_1}^2\right)$$

If F_s<F_f，then passengers are safe standing on the platform；If F_s>F_f，It is dangerous for passengers to stand on the platform。

2. This section describes whether the safety markings are set up reasonably

Establish a corresponding mathematical model to determine the magnitude of the “suction” and “thrust” of passengers on the platform, and explain the basis for setting the safety markings on the platform of high-speed rail and subway stations, and then we will continue to use Bernoulli’s principle and friction theory to build the model, while taking into account the influence of other factors such as passenger stability and safety factor in the actual situation.

In safety engineering, in order to ensure sufficient safety and avoid mistakes, it is often necessary to introduce a safety factor T. Safety factors can be used to account for unknown risk factors, such as sudden increases in wind speed, differences in passenger stability, and crowd density.

The distance d of the safety markings can be calculated by the following formula:

$$d = T\left(\frac{F_s}{F_f}\right)d_0$$

In order to establish a mathematical relationship between the safety distance and the speed of the train, an exponential function or a power function can be used to describe this growth relationship:

$$D(V) = d_0 + kv^m$$

The Pearson correlation coefficient between two variables is defined as the quotient of the covariance and standard deviation between the two variables：

$$\rho(x,y) = \frac{\operatorname{cov}(X,Y)}{\sigma x \sigma y} = \frac{E[(X - \mu x)(Y - \mu y)]}{\sigma x \sigma y}$$

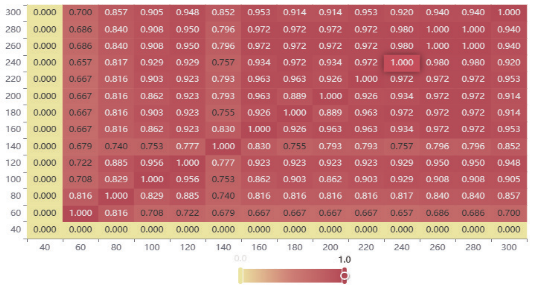
The overall correlation coefficient is defined above, and the Greek lowercase letter ρ is often used as a symbol. The Pearson correlation coefficient can be obtained by estimating the covariance and standard deviation of the sample, which is often represented by the English lowercase letter r:

$$r=\frac{\sum_{i=1}^{n}(X_i-\overline{X})(Y_i-\overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\overline{Y})^2}}$$

r can also be estimated from the mean of the standard fraction of the sample data of (Xi, Yi), so that an expression equivalent to the above equation is obtained:

$$r=\frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{X_i-\overline{X}}{\sigma x}\right)\left(\frac{Y_i-\overline{Y}}{\sigma y}\right)$$

An important mathematical property of the Pearson correlation coefficient is that the change in the position and scale of the two variables does not cause the coefficient to change, i.e., it is the invariant of the change (determined by the symbol). That is, moving X to a+bX and Y to c+dY does not change the correlation coefficients of the two variables (this conclusion holds true in both population and sample Pearson correlation coefficients).



	40	60	80	100	120	140	160	180	200	220	240	260	280	300
300	0.000	0.700	0.857	0.905	0.948	0.852	0.953	0.914	0.914	0.953	0.920	0.940	0.940	1.000
280	0.000	0.686	0.840	0.908	0.950	0.796	0.972	0.972	0.972	0.972	0.980	1.000	1.000	0.940
260	0.000	0.686	0.840	0.908	0.950	0.796	0.972	0.972	0.972	0.972	0.980	1.000	1.000	0.940
240	0.000	0.657	0.817	0.929	0.929	0.757	0.934	0.972	0.934	0.972	1.000	0.980	0.980	0.920
220	0.000	0.667	0.816	0.903	0.923	0.793	0.963	0.963	0.926	1.000	0.972	0.972	0.972	0.953
200	0.000	0.667	0.816	0.862	0.923	0.793	0.963	0.889	1.000	0.926	0.934	0.972	0.972	0.914
180	0.000	0.667	0.816	0.903	0.923	0.755	0.926	1.000	0.889	0.963	0.972	0.972	0.972	0.914
160	0.000	0.667	0.816	0.862	0.923	0.830	1.000	0.926	0.963	0.963	0.934	0.972	0.972	0.953
140	0.000	0.679	0.740	0.753	0.777	1.000	0.830	0.755	0.793	0.793	0.757	0.796	0.796	0.852
120	0.000	0.722	0.885	0.956	1.000	0.777	0.923	0.923	0.923	0.923	0.929	0.950	0.950	0.948
100	0.000	0.708	0.829	1.000	0.956	0.753	0.862	0.903	0.862	0.903	0.929	0.908	0.908	0.905
80	0.000	0.816	1.000	0.829	0.885	0.740	0.816	0.816	0.816	0.816	0.817	0.840	0.840	0.857
60	0.000	1.000	0.816	0.708	0.722	0.679	0.667	0.667	0.667	0.667	0.657	0.686	0.686	0.700
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

According to the heat map analysis, it can be seen that:

(1) When the running speed of the train is less than 120km/h, the maximum force of the passenger at the position of 1000mm from the edge of the platform is 734.17N, so the setting of the safety marking is reasonable.

(2) When the train running speed is between 120km/h and 160km/h, the force on the passenger at the position of 1500mm from the edge of the platform is between 979.84N and 1130.18N, so the setting of the safety marking is reasonable.

(3) When the train running speed is between 160km/h and 200km/h, the force on the passenger at the position of 2000mm from the edge of the platform is between 1324.26N and 1520.42N, so the setting of the safety marking is reasonable.

3. Security recommendations

(1) In summary, the railway authorities can consider dividing the platform area according to the speed of the train and indicating the corresponding location.(2) Because the high-speed driving of the railway will drive the surrounding wind speed to increase, a large pressure difference will be formed between the passengers and the train. Therefore, the railway authorities should consider optimizing the design of the platform to reduce the wind speed and pressure difference on the platform. For new or refurbished platforms, the introduction of hydrodynamic principles can be considered to optimize the design of the platform shape, so as to reduce the wind force caused by train operation.(3) It is very necessary to educate railway platform service personnel to keep pace with the times and form new thinking and new ideas to better ensure the safety of waiting passengers.

References:

[1]Wang R ,Nie L ,Tan Y .Evaluating Line Capacity with an Analytical UIC Code 406 Compression Method and Blocking Time Stairway[J].Energies,2020,13(7).

[2]Xingtang W ,Hairong D ,K. C T .Multi-Objective Timetabling Optimization for a Two-Way Metro Line Under Dynamic Passenger Demand[J].IEEE Transactions on Intelligent Transportation Systems,2020,22(8):1-11.

About the author: Yaofeng Han, male, undergraduate, research direction is Wireless broadband communications and personal communications.

Corresponding author: Changyou Cai, male (1980.09--), the Han nationality, Anshan City, Liaoning Province, China，Master, research direction: power system analysis, power electronics technology.