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Study on the safety marking setting of railway platform based on aerodynamics principle

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Abstract: As a crucial component in ensuring the safety of train operations, the scientific design, reasonable setting and effective maintenance of railway safety marking can significantly improve the overall safety of the railway system, guide the train to run orderly, and reduce the delay and conflict caused by misunderstanding or misjudgment. Through the study, the deficiencies in the existing line marking setting can be identified, and improvement measures can be proposed to improve the fluency and efficiency of train operation and enhance the public's trust in railway traffic. This paper mainly on the safety marking of railway station, according to the theoretical analysis, the model considering the train speed, passenger volume and weight, platform height and the passenger standing position, accurately calculate the passengers in the platform of airflow thrust, establish the corresponding mathematical model, in the high-speed or train at full speed, the suction on the platform. Then, a mathematical model is established according to the data, and the airflow distribution of different train speeds, platform structure and passenger characteristics is calculated by simulation, and the reasonable location of safety line is determined. Finally, the influence of different factors on the setting of safety line is analyzed, thus making relevant suggestions to ensure the safety of railway platform.

1. Introduction

With the improvement of China's technological level, the railway industry in China has made significant progress, but it has also brought some safety issues. During high-speed railway operation, due to the large passenger flow on the platform, there is a strong suction force on passengers [1]. When passengers are on the platform, the distance of the train is relatively far and there are no auxiliary support points. The train is easily balanced by the suction force, so it is necessary to set up routes to ensure that passengers behind the train are not affected [2-3]. In addition, wind pressure is affected by parameters such as human body weight and volume, so a physical model needs to be established. Through theoretical analysis, this article comprehensively considers the impact of train speed, passenger volume, weight, and passenger distance on wind pressure, in order to ensure the rationality of the safe route setting of the train station [4-5], and analyzes the variables of safety sign setting according to corresponding safety recommendations.

2. Research on the force of the platform man based on the Bernoulli equation

2.1 Construction of a theoretical model based on the Bernoulli equation

The Bernoulli equation was proposed by the Swiss scientist Daniel Bernoulli in the 18th century. It is one of the important principles in fluid mechanics. Where the local pressure is small, where the local pressure is small, it is large [6]. As shown in Figure 1

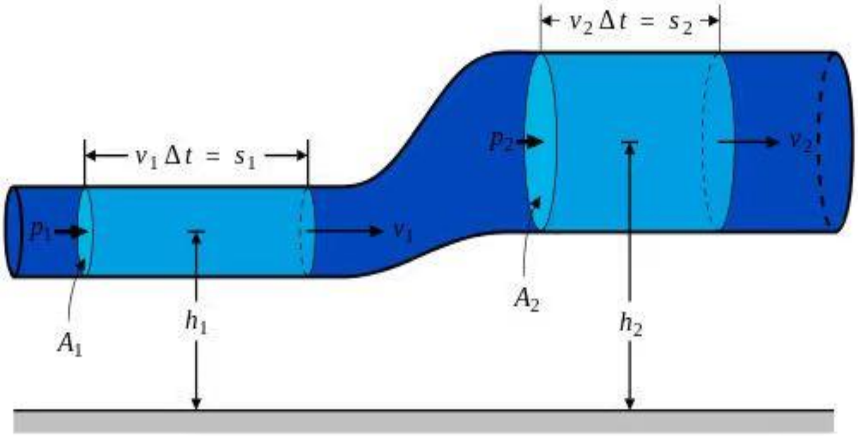

Figure 1: Schematic diagram of the Bernoulli equation

Bernoulli Equation:

$$P + \frac{1}{2}\rho V^2 + \rho \times g \times H = Constant \tag{1}$$

P fluid pressure, in: Pa; V fluid flow rate, in: m/s; ρ fluid density, unit: kg/m^3; H fluid height, unit: m; g fluid acceleration, in m/s^2;

Equation 1 shows that by taking two points on a fluid, The Pressure Energy + Kinetic Energy + Bit Energy = Constant. So without considering the presence of an energy loss, the fluid is along the streamline, and the total energy is conserved.

As the train moves through the platform at a specific speed, it propels the surrounding air, generating a rapid airflow. The Bernoulli equation tells us that where the flow velocity is high, the pressure is low. Therefore, when the train passes, passengers on the platform experience a pressure differential both in front of and behind their bodies. The higher airflow velocity in front of the body results in lower pressure, while the slower airflow behind the body leads to higher pressure. This pressure differential exerts a force on the human body, the magnitude of which can be determined using the Bernoulli equation. By considering the wind speed induced by the train's velocity, we can calculate the pressure difference experienced by an individual and estimate the dynamic pressure difference, thereby determining the magnitude of the resulting force.

2.2 Calculation of the suction size

In the design of railway safety marking, according to the principle of pressure wave, vortex and turbulence and speed and pressure relationship [7], can be used to estimate and determine the safe distance between the platform edge and train, to ensure that the high speed through the train, not dangerous to the passengers on the platform, so the fluid flow pressure distribution and the size of the force, accurate calculation. In the following actual calculations, we focus on the fluid flow and the velocity size and pressure, and calculate the suction force based on this data.

2.2.1 Calculation of wind speed

Calculation formula of theoretical wind speed:

$$V_1 = V_2 \Big/ \sqrt{1 + (kx/D)^2} \tag{2}$$

Estimated wind speed of V1; speed of V2 train; distance from the station on platform x; k air flow diffusion ratio constant; and characteristic size of the train D

It can be observed from formula 2, when the distance of people on the platform from the station x hours, the wind speed V1 is approximately equal to the train speed V2 [8]. However, with the increase of distance x, it leads to the wind speed. It will decrease by the air flow and the surrounding static air mixing, the parameter k reflects the proportion of air flow diffusion. D is the characteristic size of the train.

Experience formula for practical engineering applications:

$$V_1 = V_2[D/(D + kx)] \tag{3}$$

Estimated wind speed of V1; speed of V2 train; distance from the station on platform x; k air flow diffusion ratio constant; and characteristic size of the train D.

According to formula 3, the air velocity decreases due to jet diffusion. During the calculation of wind speed, the distance between people and the platform increases and V1 decreases.

2.2.2 Dynamic pressure calculation

Dynamic pressure is calculated according to the Bernoulli equation:

$$P = 0.5\rho\, V_1 \tag{4}$$

Where ρ is the air density, generally taking 1.225 kg/m^3.

2.2.3 Force calculation

Calculation of force F:

$$P = F \times A \tag{5}$$

A: The wind area of the human body in the direction of the opposite train. Assuming that the human body is a cylinder, the corresponding radius and area can be estimated by mass and volume.

2.2.4 Force decay with distance

Suppose that the force decreases inversely proportional with the distance d^2:

$$\text{Force at a certain distance} = F \times (1/d^2) \tag{6}$$

This paper employs a simplified model to provide a rough estimation of the effects at distances from the source, such as the airflow surrounding a fan or train in operation, which is approximately treated as radiating from a point.

This assumption is grounded in the physical phenomenon of point source emission. For instance, the intensity of light emitted by a point light source diminishes inversely proportionally to the square of the distance. This attenuation law indicates that as one moves farther from the light source, the received light intensity decreases in an inverse square relationship with the distance. Analogously, if the airflow disturbance caused by the train disseminates in a manner akin to the train's departure, the wind experienced by passengers on the platform would decrease with distance in a similar inverse square pattern.

Based to the simplified assumptions:

$$\text{Force at a certain distance} = F \times (1/d^2) \tag{7}$$

From formula 7, it can be seen that the force experienced at a specific distance is the initial force F measured at the starting distance (usually the position closest to the train on the platform) , whose decay is inversely proportional to the square of the distance d. F is the force measured at a standard distance (e.g. one meter).

2.2.5 Body volume calculation

To roughly estimate the number of people based on their collective mass, one can utilize the average density of the human body. Given that the density of the human body is approximately 1 ×103 kg/m ³ similar to that of water, this estimation relies on the assumption that the human body is homogeneous. While it's true that most of the body is composed of water, in reality, the density of the human body varies slightly due to its composition of different tissues such as bone, muscle, and fat, each with distinct densities. However, considering the human body as a whole, approximating its density to be similar to that of water remains a reasonable estimation.

The calculation formula is as follows:

$$V = m/\rho \tag{8}$$

V: Volume unit of human body: m^3; m: human body mass: in kg; ρ: density unit of human body: kg / m^3

2.3 Actual calculation

According to the above theoretical analysis, the MATLAB code is used to calculate the operation, the function is: input a person's weight, volume, the distance between the platform and the train and the speed of the train, can output the force of the passenger on the platform and visualize it.

Run the input data model to obtain Figure 2:

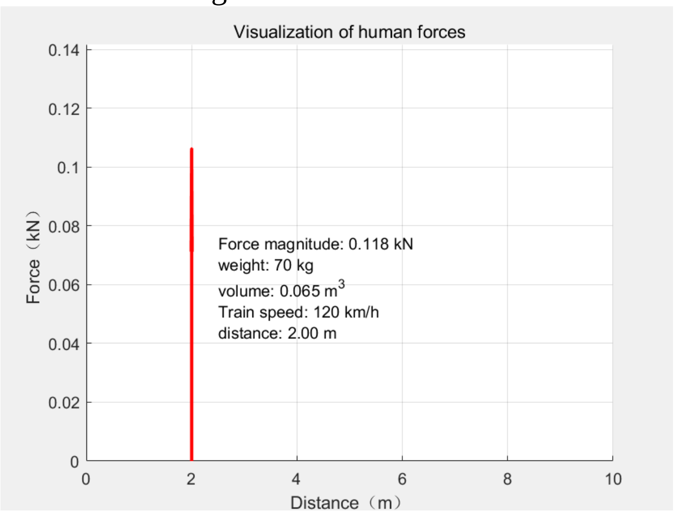

Figure 2: Data model run in Fig

3. Study on the platform safety line marking setting

3.1 Analysis of the basis of setting up the railway platform safety marking line

Article 157 of the Railway Technical Management Regulations clearly stipulates that the distance between the edge of the high platform where passenger trains are parked and the centerline of the line is 1750mm, and the distance between the safety sign line and the platform edge is 1000mm.The distance between the not high platform safety line and the platform edge is 1000mm, and the traffic speed does not exceed 120km/h; the passing speed of 1500mm is between 120km/h and 160km/h; the passing speed of 2000mm ranges from 160km/h to 200km/h. (Data source: https://www.moj.gov.cn)

In order to study the basis for setting the safety line, the high platform should be analyzed first: it can be seen that the distance of the high platform is a fixed value, and the safety distance will not change with the speed of the train. It can be explained that the standard, which also indicates that the setting of high platform safety distance can reduce the occurrence of such phenomena [9]. For low platforms, different speeds correspond to different safety distances, so we need to analyze the basis of setting the safety distance at different speeds. According to the result of the magnitude of the human force, the magnitude of the passenger force under the variable of arbitrary speed and distance can be calculated.

3.2 Thermal map of speed and distance with force

3.2.1 Description of the steps

Enter the speed of several trains and the distance between the passengers and the train through the code at one time. You can assume a more reasonable value for the weight of the passengers. All calculations are then made by modifying the code to determine the safe distance between the person and train at different train speeds. Calculate within the following range:

Train speed range: assuming a speed of 0 to 300 km/h, increasing at a speed of 20 km/h;

Platform edge to train distance: from 1000mm (1M) to 2000mm (2M), 100mm increment;

The passenger's body weight is assumed to be 70 kg. This body weight is an average value relative to the adult body weight.

3.2.2 Actual heat map

According to the above analysis, the following heat map is obtained after running the program, as shown in Figure 3.

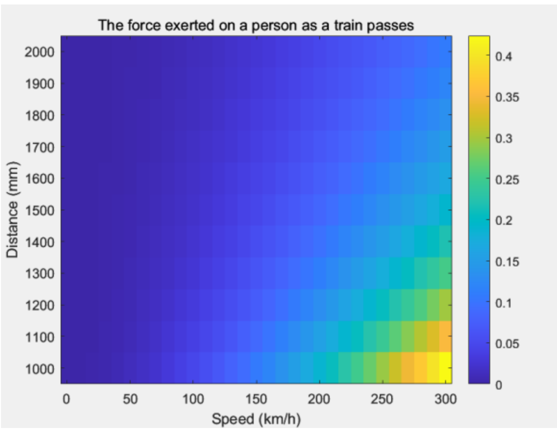

Figure 3: Thermal map of speed and distance with force

3.3 Analysis of the basis for the setting

By analyzing the heat map of speed, distance, and force, it can be concluded that when the distance between the platform and the train decreases or the train's entry speed increases, the passenger's force will also increase accordingly. In order to ensure the safety of passengers on the platform, this article needs to determine a force threshold. This threshold is used to determine under what circumstances people on the platform may lose balance.

In the process of analysis, the passenger will suffer friction on the platform, which is related to his own weight, when the passenger stands, the friction is:

$$f = \mu \times G \tag{9}$$

Among:

$$G = m \times g \tag{10}$$

Assuming that the average weight of a passenger is 70kg, his gravity is:

$$G = 70 \times 9.81 = 686.7N \tag{11}$$

The coefficient of friction between the ground and the sole is usually between 0.5 and 1, depending on where the person is located. In order to ensure safety as far as possible to take extreme conditions: friction coefficient as small as possible. For $\mu = 0.34$, the friction is:

$$f = 0.34 \times 686.7 = 233.478 \tag{12}$$

From the data, we can conclude that a lateral force exceeding 233.478N takes people out of balance.

3.4 Rationality of setting basis

(1) When the train's speed is below 120 km/h, the force exerted at a distance of 1,000 mm is less than 200N. Consequently, setting the safety line at a distance of 1,000 mm is justified.

(2) When the train's arrival speed ranges between 120 km/h and 160 km/h, the force approaches or exceeds 200N at a distance of approximately 1500 mm. To ensure station safety, the safety line should be positioned as far away as possible. Therefore, setting the safety line at 1500 mm is also deemed reasonable.

(3) When the train's speed is between 160 km/h and 200 km/h, the force on passengers may approach 200N even at a distance of 2000 mm. Hence, for safety reasons, the safety line should be set at 2000 mm.

Through analysis, it is concluded that the distance of the platform safety line established by the railway bureau is highly reasonable, effectively ensuring the safety of passengers.

4. Research on the influence of different factors on safety line marking lines

4.1 Impact of train speed

The speed of the train when entering the station is the decisive factor in the wind pressure of the passengers on the platform. The faster the train enters the station, the greater the wind pressure will be.

After running the program, the following figure is obtained; see Figure 4.

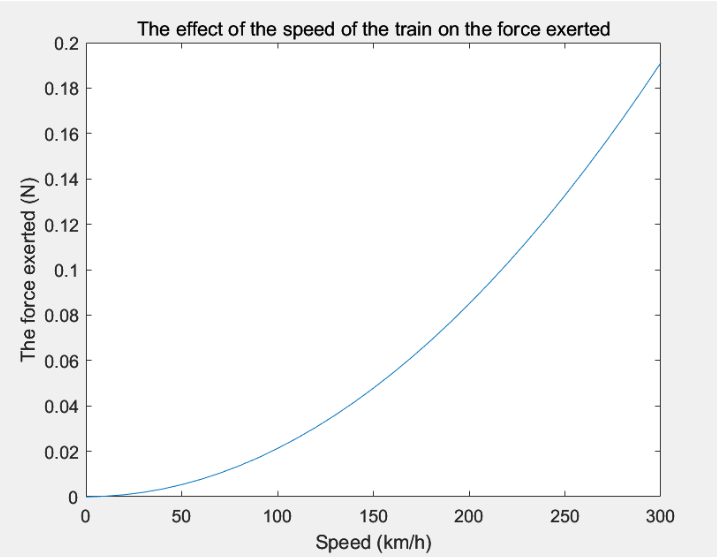

Figure 4: Relationship between pressure and train arrival speed

It is concluded from Figure 4 that the higher the speed of the train, the wind pressure.

4.2 Impact of wind speed change and other factors

Changes in train speed on high-speed railway platforms have a significant impact on passenger safety. Higher speeds may pose greater safety risks for passengers, especially in areas where passengers board and disembark, as well as in the platform waiting zones. Studies may further emphasize the necessity of implementing safety enhancements to reduce potential hazards on high-speed rail platforms.

The wind speed variation factor is dependent on the length of the train and its approximate cross-sectional diameter. As the train's length decreases and its diameter increases, the change factor for wind speed will intensify, leading to an increase in wind speed and consequently, greater wind pressure on passengers standing on the platform.

The relationship between the train diameter and the wind speed change can be obtained after the operation code, as shown in Figure 5

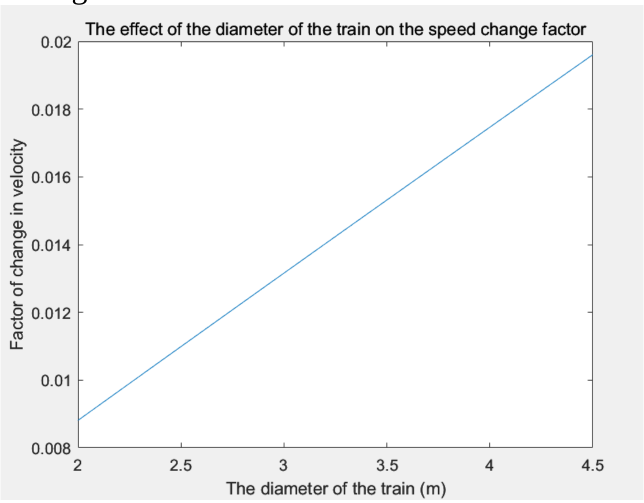

Figure 5: The relationship between train diameter and wind speed change factor

It can be deduced from the figure that as the train's diameter increases, the wind speed factor also rises, leading to an augmentation in wind speed and subsequently, an increase in the wind pressure exerted on passengers.

4.3 Safety recommendations

Through the analysis of the above influencing factors and the practical consideration, the following suggestions are proposed:

Management of train arrival speed:

(1) Compliant speed limit: The train meets the prescribed speed limit when entering the station. The restrictions depend on other factors such as track curves and platform length to ensure that trains can stop within a safe distance.

(2) The use of train control systems: Modern trains are usually equipped with advanced train control systems such as Automatic Train Protection (ATP) and Automatic Train Stop (ATP). These systems can monitor the speed of the train and take emergency braking measures when necessary to ensure that the train can enter the station at a safe speed.

(3) The changes in train speed on high-speed railway platforms have a significant impact on passenger safety. Higher train speeds may increase passenger safety risks, especially in boarding and alighting areas and platform waiting areas. Research may emphasize the need to improve safety in order to mitigate potential risks on high-speed railway platforms [10].

Suggestions for the platform design:

(1) Adequate Platform Width: The platform must possess sufficient width to guarantee that passengers can move freely, board and disembark with ease, and accommodate a high number of passengers during peak hours. The determination of platform width requires consideration of train length and passenger flow dynamics.

(2) Platform Edge Marking: Warning lines should be clearly indicated at the edge of the platform to guide passengers away from the tracks, thereby minimizing the risk of falls and collisions.

(3) Protective Railings and Barriers: Sturdy protective railings or barriers should be installed at the platform's edge to prevent passengers from accessing the track area. These railings must comply with relevant standards and undergo regular inspections and maintenance.

(4) Integrating Safety Engineering and Sustainable Development Principles: The safety design of railway platforms is studied with consideration for multiple factors, including platform structure, passenger flow, emergency evacuation and environmental impacts.

5. Conclusions

Based on the aforementioned analysis, this paper utilizes the Bernoulli equation, aerodynamic principles, thermal mapping, and mechanical modeling to visualize potential scenarios on railway platforms through modifications to the model. This model offers greater adaptability to parameters associated with various modes, enabling it to fit different scenarios. Simultaneously, the imagery derived from this model allows for an intuitive understanding of how different factors influence experimental outcomes, facilitating more effective modifications to address any issues. In the future, optimizing the layout of line markings and enhancing reflective performance designs can improve the visibility of trains during nighttime or severe weather conditions, thereby reducing lighting energy consumption. Furthermore, the implementation of intelligent monitoring systems can help minimize unnecessary inspection and maintenance tasks, further conserving energy and decreasing carbon emissions.

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