Study on the Influence of the Presence of the Wind Barrier on the Aerodynamic Performance of Maglev Train

Xianli Li and Dan Zhou

ABSTRACT

The aerodynamic performance and operational stability of the high-speed maglev train are affected under the windy environment. In order to make the train safe operation, it is an effective measure to install a wind barrier along the route. Based on three-dimensional, unsteady, $N-S$ incompressible equations and standard $k-\varepsilon$ two-equation models, the aerodynamic performance of TR08-type maglev train before and after installation of wind barrier is simulated numerically under the crosswind. The flow field structure around the train, the surface pressure of the train and the aerodynamic action coefficient were studied. And the difference of the aerodynamic performance of the maglev train before and after the installation of the wind barrier was obtained. Research indicates that the numerical results were in agreement with the experimental data and the deviation between them was below 10%. After installation height of 4.037m wind barrier, the maximum positive pressure on the train surface increases, which is increased by 5%, while the maximum negative pressure of the train surface reduces by 72%. The drag coefficient of the head car increases. The tail drag coefficient decreases. The lateral force coefficient of the head and tail cars is reduced.

Key words: maglev train the wind barrier surface pressure flow field structure
INTRODUCTION

With the maglev train technology continues to mature, and at the same time maglev train has many advantages\textsuperscript{[1]}, such as fast speed, low running cost and low energy consumption, less maintenance, favorable environmental protection, high safety, small turning radius and strong climbing ability etc. So maglev trains get a large area to promote.

China has a vast geographical and diverse climate, along the train vulnerable to the impact of the wind, such as the maximum wind speed may reach 30m/s at along the Beijing-Shanghai\textsuperscript{[2]}. The maglev train runs at high speed. In the wind conditions, the lateral force will affect the transverse magnetic gap stiffness and the lift force will make the magnetic gap on both sides of the inconsistency. In order to reduce the impact of wind on the safe operation of the train, we can install the wind barrier along the line. At present, there are few studies on the over-wind barrier of maglev train at home and abroad. The study on the aerodynamic performance of maglev train is mainly the research of drag performance, such as Mo Shuangxin, Takao K, Zhou Dan\textsuperscript{[3-5]}, And the aerodynamic performance of the train in the wind environment, such as Li Renxian, Li Shouhua\textsuperscript{[6-7]}. For the study of the aerodynamic performance of the train wind barrier (windscreen, sound barrier), the main focus is on the train, such as Yang Bin, Liu Jiqiang, Belloli M.\textsuperscript{[8-10]} Therefore, in order to reduce the impact of wind on the smooth and safe operation of maglev train, it is necessary to study the aerodynamic performance of train wind barrier.

1 NUMERICAL SIMULATION OF THE THEORY, MODEL, REGION AND BOUNDARY CONDITIONS

1.1 Computational theory and model

The three-dimensional, unsteady and incompressible turbulent flow is used in the flow field around the train under the crosswind. There are some governing equations to describe the flow field around the train, which is including continuity equations, momentum equations, energy equations, equations and standard two-equation models.

The calculation model is including the head car (4.99H) + tail car (4.99H), which is 2 car group. We choose 1: 1 ratio TR08 as the maglev train model. It is total length 9.98H. The model of the maglev train is shown in Figure 1.
indicates the top of the train from the bottom of the track. In order to study the aerodynamic performance of the interaction between the wind barrier and the train, the positional relationship between the train and the wind barrier model is shown in Figure 2.

1.2 Computational domain

The calculation area of flow field should theoretically be an infinite space. Far away from the car, the impacts of the aerodynamic performance of the train are less. And computing resources are limited. But computational domain can not be too small. In summary, the flow field calculation area length, width, height are 69.7H × 29.3H × 11H. The flow field calculation area is shown in Figure 3. In order to avoid the influence of the entrance boundary conditions, the trailing distance of the trailer nose is 14.7H. In order to avoid the influence of export boundary conditions on the flow field and tail vortex around the train, the distance from the exit boundary is 40.3H.
1.3 Mesh and boundary conditions

Meshing is done by Gambit, which is the Fluent pre-processing software. Using the sliding mesh technique and choosing the unstructured grids to discrete the model. The grid view of the maglev train is shown in Figure 4. The adaptability of the unstructured grid is great, and the grid division of the train surface can save time.

In order to converge the computational domain, the boundary of the computational domain must be set. The boundary of the computational domain is set as shown in Figure 5. The two faces before and after of the calculation of the train are defined as pressure entrances. Under the cross wind condition, the windward side is set as the velocity inlet boundary condition and the leeward side is set as the pressure exit boundary condition. The wind speed is 20 m/s. The surface of the windshield, the upper and lower surfaces of the calculation domain, and the surface of the maglev train are defined as the wall boundary. The computational domain uses the sliding mesh technique. So we need to define the sliding boundary condition. And the speed of the slip surface is 55.56 m/s.

1.4 Definition of aerodynamic coefficient

For ease of analysis, define the aerodynamic coefficients as follows:

\[
C_d = D/(0.5 \rho v^2 S) \tag{1}
\]

\[
C_c = C/(0.5 \rho v^2 S) \tag{2}
\]

In the formula (1) (2): \(\rho\) is the air density, the value of \(\rho\) is 1.255 kg/m\(^3\). \(v\) is the flow velocity, the value of \(v\) is 55.56 m/s. \(S\) is the reference area, the value of \(S\) is 11.827 m\(^2\). \(D\) is the resistance. \(C\) is the lateral force. \(C_d\) is the resistance coefficient. \(C_c\) is the lateral force coefficient.

2 THE RESULT AND ANALYSIS OF NUMERICAL SIMULATION

2.1 The flow field structure and pressure around the maglev train

When \(t=2.25\) s, along the maglev train at different positions of the cross-section are shown in Figure 6. In order to better study the train around the pressure distribution and the flow field structure under the crosswind, five sections of the
maglev train are intercepted at different locations. We select two sections on the head car and the head car symmetrical position of the tail car also select two sections. We also select a section in the middle of the train model. The five sections are X1, X2, X3, X4 and X5. They are 5m, 15m, 27m, 39m and 49m respectively from the head of the car.

Figure 6. Cross section of different.

Figure 7. Before installing the wind barrier, the flow field structure and pressure distribution around the maglev vehicle.
Before and after installation of the wind barrier, the flow field structure and pressure cloud around the magnetic vehicle are shown in Figure 7 and 8. Before installing the wind barrier (Figure 7), the pressure distribution on the upwind side of the train at different locations is positive. Due to the influence of the train, the pressure distribution on the leeward side is negative. In the different positions of the cross-section, it only produces a whirlpool in the leeward side of the train. But the shape of the whirlpool is slightly different. After installing the wind barrier (Figure 8), the pressure distribution on the leeward side of the train is positive and the left side of the wind barrier and the train between the wind surface form a local negative pressure distribution. In different positions of the cross-section, the flow field structure is very different because it is influenced by the wind barrier. Due to the left wind barrier and the train between the wind side by the main whirlpool, a vortex flow is formed at \( X_1 = 5 \)m to the same two smaller swirls. And the vortex of the two vortex is basically on the same level. In the \( X_2 = 15 \)m, \( X_3 = 27 \)m and \( X_4 = 39 \)m three positions, the left wind barrier and the train between the wind surface also form two vortex in the opposite direction of the whirlpool. While the vortex of the two whirlpools is at different heights. From \( X_2 \) to \( X_4 \), the radius of the above vortex has increased. At \( X_5 = 49 \)m, there is three vortices between the left wind barrier and the train's windward side. And the eddy direction of the larger
radius is opposite to the lower vortex. The vortex of the following two small vortex is basically on the same horizontal line. After installing the wind barrier, between the left side of the wind barrier and the train windward side of the whirlpool show a trend that the first split after the split from the head to the rear direction. Between the leeward side of the train and the right wind barrier along the train are not swirling eddy. The vortex of the main vortex of the leeward side of the train is higher than before the installation of the wind barrier. The above description shows that after installing the wind barrier, the flow field around the train becomes noticeably complicated.

2.2 Surface pressure distribution of maglev train

In a crosswind environment, high-speed maglev levines are subject to resistance and lateral forces applied by transverse winds. Excessive lateral force causes the magnetic levitation train to produce a large inclination and affect the smoothness and safety of the train. The size of the lateral force is the pressure difference between the windward and the leeward side of the train. Reducing the pressure difference between the windward side and the leeward side of the train can effectively reduce the lateral force of the train.

Before and after installing the wind barrier, the pressure on the train surface is respectively shown in (a) and (b) of Figure 9. We can obtain from the figure: whether it is installing a wind barrier before or installing a wind barrier after, the maximum positive pressure on the surface of the train is at the tip of the head. Before installing the wind barrier, most of the train's windward surface is positive pressure. In the windward side of the train and the top of the surface of the excessive appear concentration of negative pressure area. The top of the train

![Diagram](image)

( a ) Before installing the wind barrier
Installing the wind barrier before and after, the local surface pressure distribution of the head and tail of the maglev train is shown in (a)-(d) of Figure 10. It can be seen from the figure: after installing the wind barrier, the negative pressure concentrated area of the head car front and body transition area decreases is a negative pressure distribution. Most of the leeward side of the train is also positive pressure. After installing the wind barrier, most of the windward surface is negative pressure and most of the top is a positive pressure distribution.
and the negative pressure value also decreases. Before installing the wind barrier, the negative pressure concentration area of the head and tail of the train is biased towards the windward side. After installing the wind barrier, the negative pressure center of the head and tail cars are concentrated at the top of the train.

Before installing the wind barrier, the maximum positive pressure of the train surface is 2047Pa and the maximum negative pressure of the train surface is 3886Pa. While after installing the wind barrier, the maximum positive pressure of the train surface is 2146Pa and the maximum negative pressure of the train surface is 1081Pa. So after installing the wind barrier, the maximum positive pressure of the train surface increase slightly, which is increased by 5%. And the maximum negative pressure of the train surface is reduced by 72%.

2.3 Comparison of variation laws of aerodynamic coefficient

Installing the wind barrier before and after, the aerodynamic coefficient calculation results are shown in table I. We can obtain from the table: installing the wind barrier before and after, the change of each coefficient is obvious. Before installing the wind barrier, the drag coefficient of the head car is much smaller than the drag coefficient of the tail car and the lateral force coefficient of the head car is greater than the lateral force coefficient of the tail car. After installing the wind barrier, the drag coefficient of the head car is increased. The drag coefficient of the tail car is reduced. The drag coefficient of the head car is also less than the drag coefficient of the tail car. The lateral force coefficient of the head and tail cars is reduced. And after installing the wind barrier, the lateral force coefficient of the head car is much smaller than the lateral force coefficient of the tail car.

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<th>TABLE I. CALCULATION RESULTS FOR AERODYNAMIC COEFFICIENT UNDER INSTALLING THE WIND BARRIER BEFORE AND AFTER.</th>
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<td>Drag coefficient</td>
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3 CONCLUSION

In this paper, the wind speed is 20m/s, the train speed is 55.56m/s. Through the numerical simulation method, the differences in the aerodynamic performance of the maglev train before and after the installation of the wind barrier are studied. Get the following main conclusions:

(1) After installing the wind barrier, there is a local negative pressure between the wind barrier and the flow field around the train becomes complicated.

(2) The maximum positive pressure of the train surface increases, which is increased by 5%. While the maximum negative pressure of the train surface is reduced by 72%.

(3) The drag coefficient of the head car increases. The tail drag coefficient decreases. The lateral force coefficient of the head and tail cars is reduced, and the lateral force coefficient of the head vehicle tends to zero.

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