# Dynamic response analysis of high-speed maglev train

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**Research Article**

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# Dynamic response analysis of high-speed maglev train

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## Abstract

Maglev train is suspended through the surrounding track, which overcomes many disadvantages caused by the direct contact between the wheel and rail of traditional vehicles, such as excessive friction. It has the advantages of high speed, comfortable riding, less maintenance, strong climbing ability, and so on. However, when the train is running at high speed, it will be subjected to a strong unsteady aerodynamic load. The violent disturbance of aerodynamic load will inevitably lead to the corresponding feedback of electromagnetic force and the change of the suspension gap, which will affect the stability and safety of the train.

***Keywords***: High-speed maglev train; Aerodynamic load; Electromagnet fluctuation

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# Introduction

As a new type of transportation tool with good development prospects, the maglev train has received more and more attention. The suspension operation of the train overcomes many disadvantages caused by the direct contact running of traditional vehicles through wheel rail, such as excessive friction, which greatly improves the running speed of the train and prolongs the service life of the train. In the past decades, China has actively responded to the call of the state, vigorously developed the research on maglev technology, quickly made extraordinary achievements, and can independently industrialize the production of medium and low-speed maglev trains. China's research on the maglev train is continuing, moving towards a faster and more stable goal. At present, the research on the key technologies of the high-speed maglev train with a speed of 600 km / h has been started, and the first experimental sample vehicle will be offline in 2019. However, with the increase in speed, the aerodynamic load environment of the train has become more complex, so it is necessary to research the high-speed maglev train with a speed of 600 km / h. Under this background, taking the Shanghai TR08 Maglev train as a model, this paper studies the stability of the 600 km / h high-speed maglev train running on the open line and the intersection of two trains under aerodynamic load.

## The dynamic model of the maglev train with three vehicles

The maglev vehicle structure is mainly composed of the vehicle body and suspension frame. The car body adopts a sandwich aluminum light elastic structure with a streamlined shape design. The suspension frame is a light high-strength structure combining cast aluminum and extruded aluminum. Each car contains four suspension frames: a suspension frame, crossbeam, longitudinal beam, and supporting skid. The suspension frame is composed of two bow-shaped suspension arms, an upper connecting piece, and a lower connecting piece. The sandwich structure is connected with the carriage bottom plate by bolts and rivets and is used to install various drawer-type chassis equipment. The function of the suspension frame is to load electromagnets and transmit the suspension force, guiding force, traction force, and braking force to the vehicle body through the secondary suspension system. The suspension and guiding electromagnets are elastically connected through rubber pads or joints to the suspension frame. The suspension frame is connected with the car bottom plate through an air spring, rocker arm, swing rod, traction pull rod, and other mechanisms. The suspension frame is connected with the car body through the pendulum. The car body also has 6 degrees of freedom. The swing rod rotates in the direction of harmony relative to the bolster and the car body. The primary suspension of the vehicle is independently provided by the supporting rubber parts or joint structures of the traction electromagnet and the guide (including braking and replacement) electromagnet. The secondary system's vertical, horizontal, and longitudinal traction is independently provided by an air spring, suspender, and horizontal additional spring / stop and traction device. The dynamic model of the single-vehicle TR08 maglev train is shown in **Fig. 1**

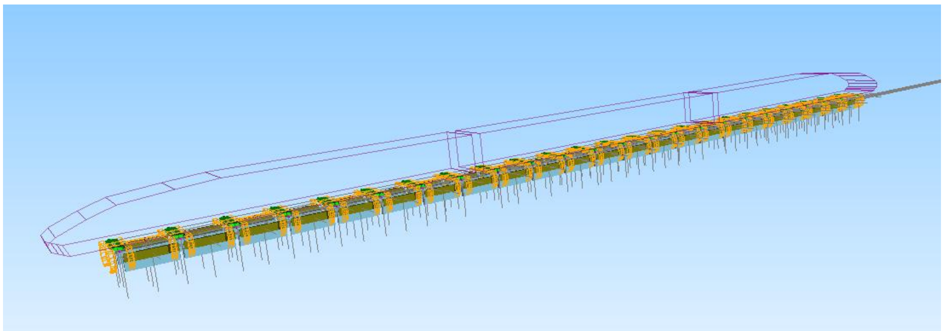

**Fig. 1** Dynamic model of TR08 maglev train

## Analysis of train response under aerodynamic load

In SIMPACK, the running speed of the maglev train is set as 600 km/h, and the aerodynamic load during open line operation is applied to the vehicle body dynamic model as an excitation. Through SIMPACK and MATLAB joint simulation, the dynamic response of the train can be obtained.

**(1) Stability index calculation results**

Through calculation, we can get that the stability index of the first car is 4.0769; The stability index of CRRC is 5.5554; The stability index of the tail car is 8.5136. It can be seen from Table 1 that the calculated stability index value is large, which does not meet the riding requirements and the comfort of the tail car is the worst, so it needs to be optimized.

**(2) Vertical displacement of the vehicle body**

Through SIMPACK post-processing, we can get the vertical displacement curves of the head car, middle car, and tail car body when the maglev train is running, and the results are shown in **Fig.2**.

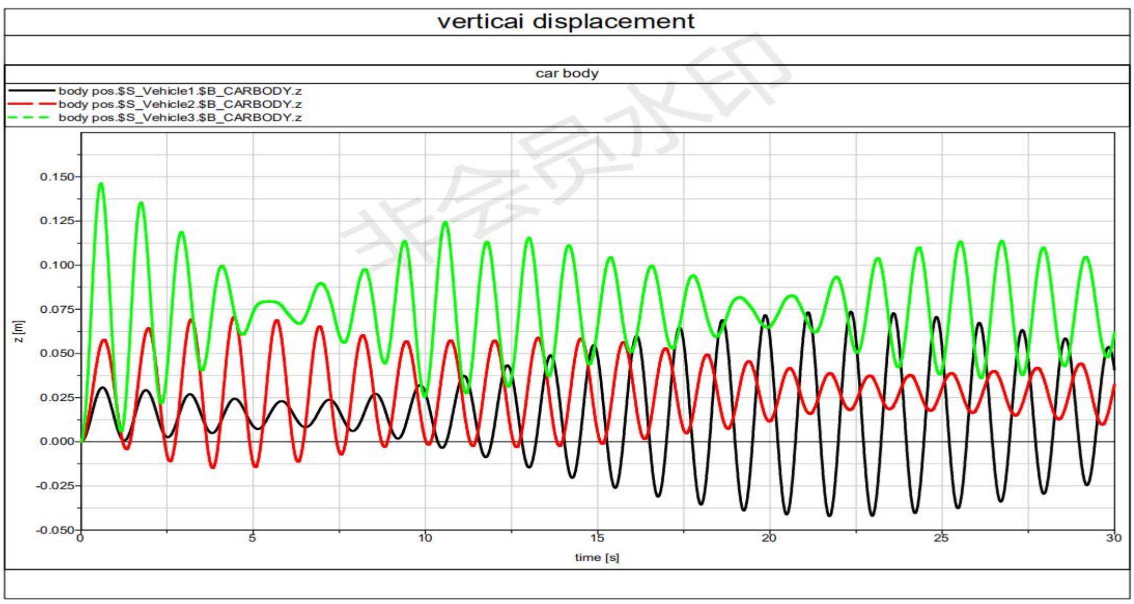


**Fig.2 Vertical displacement curve of head car, middle car, and tail car body**

After SIMPACK post-processing, we can get:

(1) The maximum displacement of the head carriage in the positive direction of the Z-axis (i.e. the body moves upward) is 73.75 mm, and the maximum displacement in the negative direction of the Z-axis (i.e. the body moves downward) is 42.26 mm;

(2) The maximum displacement of the middle carriage in the positive direction of the Z-axis (i.e. the car body moves upward) is 70.59 mm, and the maximum displacement in the negative direction of the Z-axis (i.e. the car body moves downward) is 14.81 mm;

(3) The maximum displacement in the positive direction of the Z-axis (i.e. upward movement of the car body) of the tail car carriage is 146.19 mm.

It can be seen that the vibration amplitude of the railcar compartment is the largest and the maximum amplitude is 146.19 mm.

**(3) Fluctuation of suspension clearance**

When the maglev train is running, the suspension gap fluctuation curve of the head, middle, and tail cars is shown in **Fig.3** (taking a suspension magnet as an example).

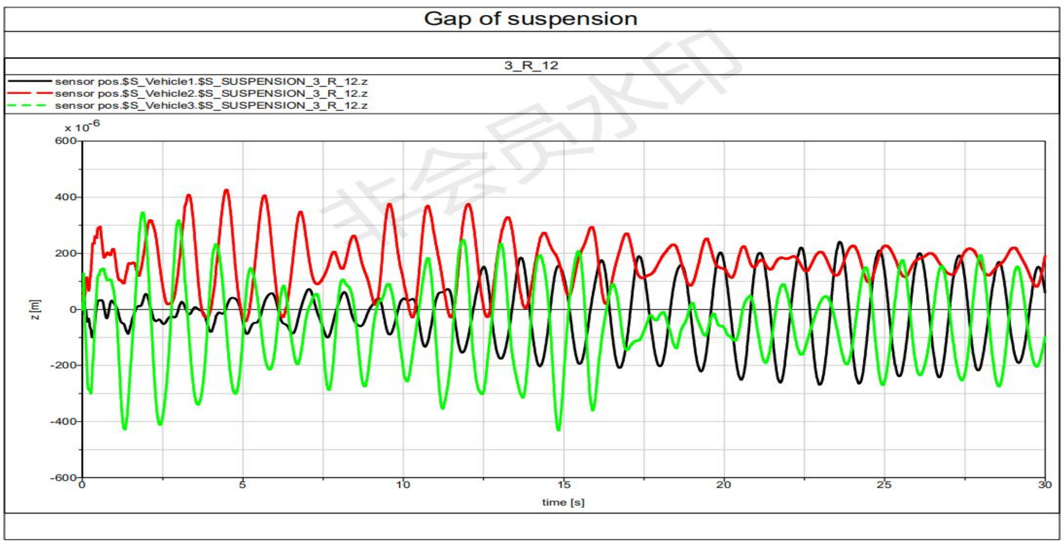


**Fig.3 Fluctuation curve of suspension clearance of head car, middle car, and tail car**

7 pairs of suspension electromagnets are equipped with sensors (as shown in

**Fig.4**). Through SIMPACK post-processing calculation, we can get the fluctuation values of 7 suspension gaps on each train corresponding to the position of suspension electromagnets, as shown in **Table 1.**

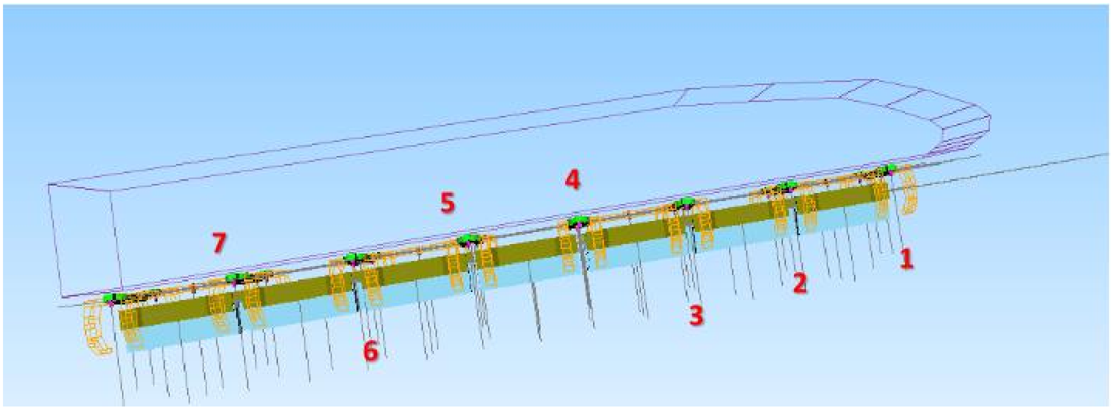


**Fig.4 7 pairs of sensors on a maglev train**

**Table1 fluctuation value of suspension clearance**

| GAP | 1（mm） | 2（mm） | 3（mm） | 4（mm） | 5（mm） | 6（mm） | 7（mm） |
|---|---|---|---|---|---|---|---|
| Head Car | 1.168 | 0.476 | 0.450 | 0.565 | 0.735 | 0.618 | 1.589 |
| Middle Car | 1.729 | 0.687 | 0.427 | 0.498 | 0.781 | 0.770 | 1.625 |
| Tail Car | 1.874 | 1.408 | 1.140 | 1.226 | 1.037 | 1.158 | 3.968 |

In addition, the fluctuation of suspension clearance at the joint of the first and middle cars is 2.178 mm, and that at the joint of the middle car and the tail car is 2.410 mm.**Fig.5** shows the fluctuation curve of suspension clearance of the whole vehicle group.

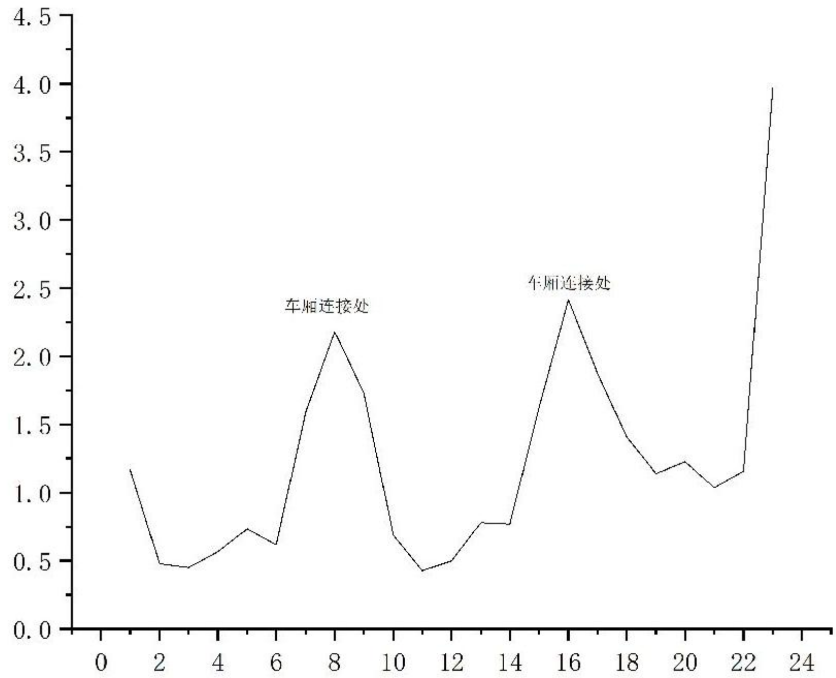


**Fig.5** Curve of Maglev gap fluctuation value of complete vehicle set

From the above calculation results, we can conclude that:

(1) among the three carriages, the fluctuation value of the suspension clearance of the head car is the smallest, followed by the middle car, and the fluctuation value of the tail car is the largest;

(2) for each carriage, the fluctuation value of the head and tail floating clearance is the largest, and the fluctuation value in the middle of the car body is small;

(3) The fluctuation value at the junction of the carriage is large and the suspension fluctuation value at the junction of the middle car and the tail car is greater than that at the junction of the first car and the middle car;

4 the maximum fluctuation value of suspension clearance of the whole vehicle is 2.410 mm.

# Declaration

## Availability of data and materials

Not applicable.

## Competing interests

The authors declare that there is no conflict of interest.

## Authors' contributions

Mengjuan Liu: Data curation, Writing- Original draft preparation, Software, Formal analysis.

Han Wu: Conceptualization, Methodology, Funding acquisition, Article check, Supervision.

Xiaohui Zeng: Supervision.

Bo Yin: Improve data.

Zhanzhou Hao: Improve data.

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Not applicable.

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