Test Results on the new vehicles of the JR-Maglev

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Keywords

JR-Maglev, aerodynamics, micro pressure wave, levitation, guidance

Abstract

We have been conducting test runs on the Yamanashi Maglev Test Line since April 1997. In July 2002, we introduced two new vehicles into the Yamanashi test line for the purpose of improving aerodynamic characteristics and studying cost reduction technologies. We obtained the test data of these new vehicles, and the new vehicles performed as we expected.

In December 2003, we carried out the running test at the maximum speed of 581 km/h, using the original MLX01 train. Through this running test, we confirmed that JR-Maglev has the high performance of reliability, and that JR-Maglev system has reached to technical maturity.

On the basis of these test data, we will make the specification and the design standard of the vehicle for commercial operations.

1 Introduction

We have been conducting test runs on the Yamanashi Maglev Test Line since April 1997. The running tests consist of two phases. The first phase of the running tests was from 1997 to 1999. We achieved the maximum speed at 552 km/h, which is the designed maximum speed, on April 14, 1999. We also carried out the passing test at a relative speed of 1003 km/h on November 16, 1999. The second phase is from 2000 to March 2005. We are conducting the running tests in order to solve the following issues: verification of reliability and durability, improvement of aerodynamic characteristics, and reduction of the initial and operational cost.

For the purpose of improving aerodynamic characteristics and studying reduction of the initial and operational cost, we introduced two new vehicles and two new bogies into the Yamanashi test line in July 2002. We obtained the data of these new vehicles, which show that the new vehicles performed as we expected. At the same time, in order to verify reliability and durability, we continue to carry out the running test using the original MLX01 train, which is the original type of Maglev vehicle.

In December 2003, we conducted the maximum speed test over the designed speed using the original MLX01 train. The train ran at a speed of 581 km/h, and set the world speed record. Through this running test, we confirmed that JR-Maglev system has the high performance of reliability, and that JR-Maglev system has reached to technical maturity.

In this paper, we introduce the test results of these new vehicles, and the running test at the speed of 581km/h using the original train.

2 Running test results of the new vehicles

2.1 Characteristics of levitation and lateral guidance

The vehicle of the JR-Maglev system levitates at the electromagnetic balance position with the bogie load mass, which is lower than the center of the levitation coils including the electrical circuit like “8” character. The distance between the center of the ground coil and the electro-magnetic balance position is called balanced displacement. Fig. 1 shows the relationship between the vehicle speed and the balanced displacement. The distance between the coil in the Super Conducting Magnet (SCM) and the ground coil of the guideway is 10 mm shorter than that of the original bogies. In addition, the maximum rating magnetomotive force of the SCM on the new bogie is 750 kA, while that of the original SCM is 700 kA. Consequently, the SCM does much better performance. These designs were determined to secure the static stability of the levitation and lateral guidance at low speed, and to increase the weight margin of service devices which are necessary for commercial operation.

As shown in Fig. 1, the balanced displacement of the new bogie is smaller than that of the original bogies, and above mentioned improvement results in the larger levitation force. The experimental results agree with the calculated values of the balanced displacement. It indicates that the characteristics of levitation match the design.

Fig. 2 shows the lateral displacement in the curved section. On the Yamanashi Maglev Test Line, the minimum curvature radius is 8,000 m, and the maximum cant is 10 degrees. The centrifugal force in the curved section balances with the force of the vehicle weight at the speed of 420 km/h. Therefore, in the curved section, the center of the lateral direction of the bogie displaces statically toward inside at speeds below 420 km/h and toward outside at speeds above 420 km/h. As shown in Fig. 2, the lateral static displacement of the bogie with 750kA SCM is smaller than that of the the bogie with 700kA SCM, and it is found that the electromagnetical force of the lateral guidance becomes large in proportion to the magnetomotive force.

Thus, both the characteristics of levitation and lateral guidance were what we designed.

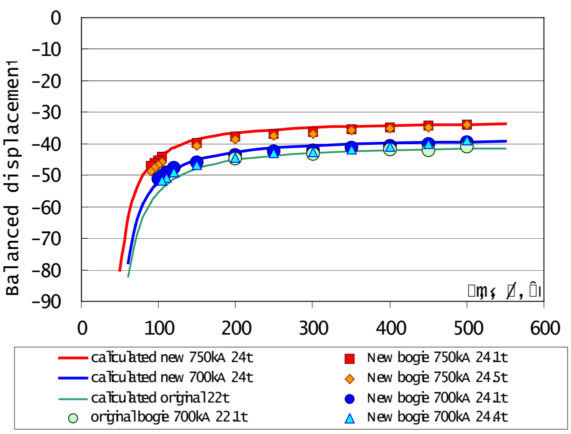


Fig1. Balanced displacement vs.vehicle

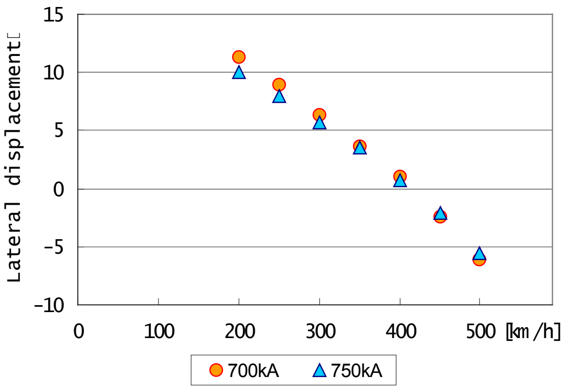


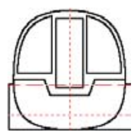
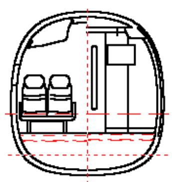
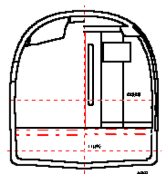
Fig2. Lateral displacement vs.vehicle speed, on a curved guideway section

2.2 Improvement of aerodynamic characteristics

In order to improve aerodynamic characteristics of the vehicle, new shape of the car body was developed on the base of the results obtained in the first phase of the vehicle running test. The new vehicles have the following three main features.

First of all, the nose length of the leading car was extended from 9.1 m to 23 m to reduce the micro-pressure wave and low frequency noise, which is generated when the train rushes into tunnels or tunnel hoods. When we selected the nose shape of the leading car, we adopted “Vwall theory” for the first time. It was invented to minimize micro-pressure wave. This theory is that the scale of micro-pressure wave relates the normal component of the flow velocity on the imaginary surface of a tunnel or a tunnel hood in the open section, and the micro-pressure wave is reduced by decreasing the

Table.1 Comparison of two cross

	Original Sub-round	New model Square shape
Shape of cross-section  Bogie part		
Area	$7.8m^2$	$8.1m^2$
Concept	Priority on structure for air-tight load	Priority on aerodynamic performance

Vwall value. The normal component of the flow velocity on the imaginary surface at the tunnel or the tunnel hood in the open section is calculated by using Computational Fluid Dynamics (CFD) analysis.

Secondly, in order to reduce the local outer noise generated at the front edge of the leading bogie, the change of the cross-section on the front side of the leading bogie is moderated by extending the distance between the nose tip and the front edge of the leading bogie from 3.7 m to 6.4 m.

Thirdly, the new vehicles adopted a square shape at the lower part of the general cross-section as shown Table1. On the original vehicles, the air flow turbulence was generated at the each bogie part at high speed run, because the cross-section difference between the car body and the bogie was large. As a result, this phenomenon influenced the aerodynamic characteristics concerned with air drag and environment. Therefore, in order to decrease the cross-section change between the middle part of the body and the bogie part, the new vehicles adopted a square shape at the lower part of the general cross-section.

2.3 Running test results for aerodynamic characteristics

2.3.1 Comparison between CFD analysis and test data

Fig. 3 shows the comparison between CFD analysis and test data in a running condition as the leading car, and Fig. 4 shows in a running condition as the tail car. CFD analysis and test data for the pressure on the upper surface of the vehicle matched well. These results are what we aimed.

Fig. 5 shows CFD analysis results and test data for pressure fields around the train. With the condition of a 500 km/h run, the pressure difference caused by the difference of the nose figures is distinctive at the distance of 15 m or less from the vehicle. However it becomes extremely small at the distance of 25 m or more.

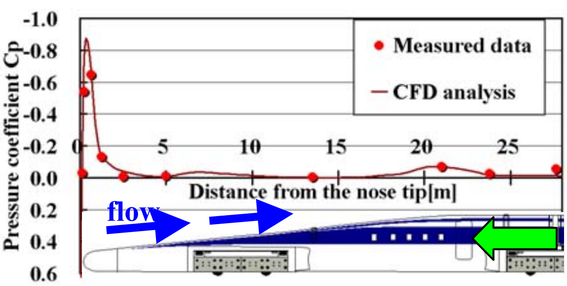


Fig.3 Surface pressure of the leading

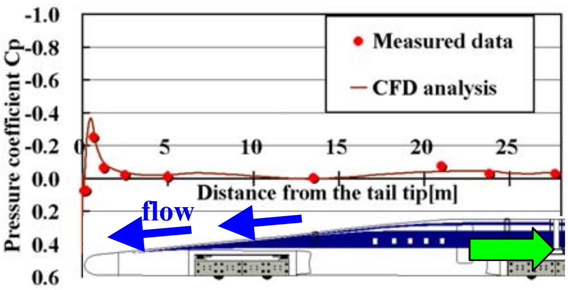


Fig.4 Surface pressure of the leading car

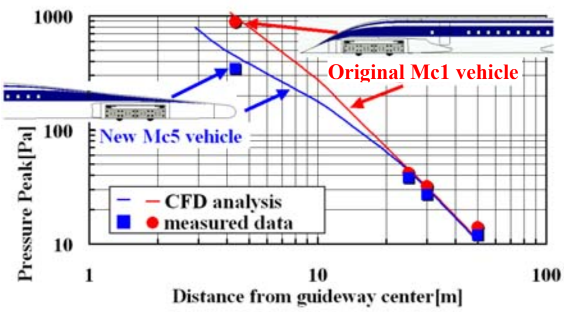


Fig.5 Influence of vehicle pressure field

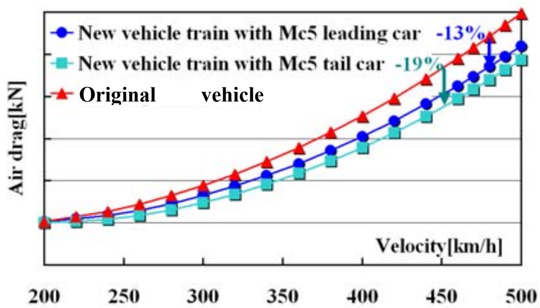


Fig.6 Air drag

2.3.2 Air drag

The measured air drag data about three-car train is shown in Fig. 6. The air drag of each train increases in proportion to velocity raised to the second power. The new vehicle train, when it is both as a leading and tail car, has less air drag than the original vehicle train. The results indicate that the air drag can reduce 10% or more than that of the vehicle, and that results in saving much more energy.

2.3.3 Micro pressure wave

The evaluation of the vehicle for micro-pressure waves is made by examining a pressure gradient of the compression wave near a tunnel entrance. The pressure gradient data measured at a tunnel wall 500 m from the tunnel entrance is shown in Fig. 7, in the case of a train rushing into a tunnel with a tunnel hood at a speed of 500 km/h. Although the reduction effect of the pressure gradient caused by the tunnel hood is large, the new Mc5 vehicle reduces the pressure gradient to 82% of the original Mc1 vehicle.

2.3.4 Low frequency noise

Fig. 8 shows the waveforms of sound pressure of low frequency noise measured at a location 70 m from the tunnel hood and 100 m from a tunnel hood entrance. Around at the minus peak of sound pressure, the absolute value by the new Mc5 vehicle reduces 76% by the difference in nose figure. The results clearly show the effects of a nose figure improvement.

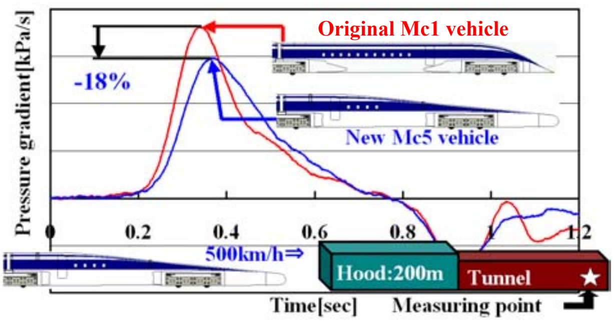


Fig.7 Comparison of pressure gradients

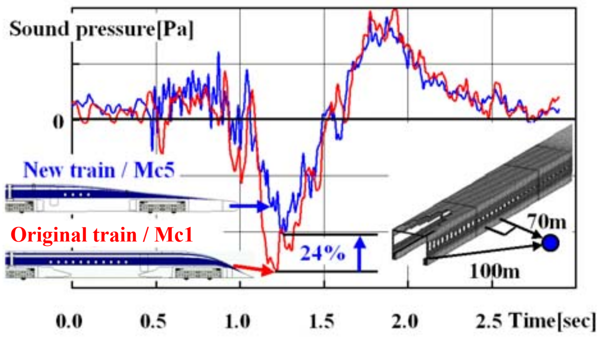


Fig.8 Comparison of low frequency noize

2.3.5 Outer noise

Fig. 9 shows the outer noise waveforms measured by a parabola microphone located about 4.5 m away from the train. The noise level of the new train from the front edge of the leading truck becomes 3 to 4 dBA lower than that of the original MLX01 train. These reductions are obtained by the extension of the distance between the nose tip and the leading truck from 3.7 m to 6.4 m, and by the moderation of the cross-section change in the front side of the leading truck in order to suppress the flow velocity increase into the leading truck.

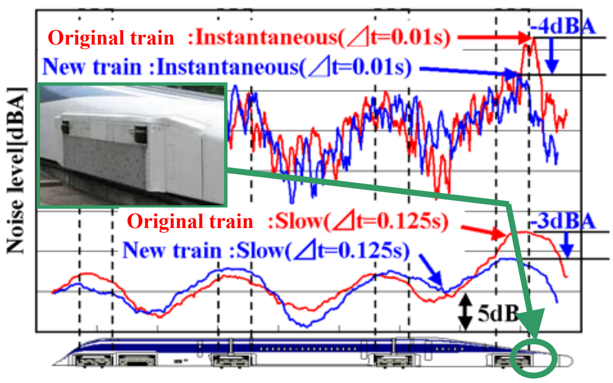


Fig.9 Comparison of outer noise

2.3.6 Noise in the cabin

In terms of noise in the cabin of the M3 intermediate vehicle, the noise transmission from windows is larger than that from the ceiling panel, side panel and floor panel. Its main frequency range is from 160 Hz to 500 Hz in which the mass law is not so effective. As shown Fig. 10, the transmission loss of the intermediate vehicle M3 becomes theoretically small in about 300 Hz range. In order to solve this, the air gap between the outer and the inner window is enlarged from 6 mm(M3:Original) to 75 mm(M4:New). Therefore, the transmission loss increases in the frequency range of 250 Hz or more, and noise in the cabin is reduced.

By using this countermeasures, the noise in the cabin of the new M4 intermediate car is reduced remarkably in the frequency range of 300 Hz or more, and the overall noise level in the cabin is decreased 3 dBA smaller than the M3 intermediate car under the running conditions, as shown in Fig.11.

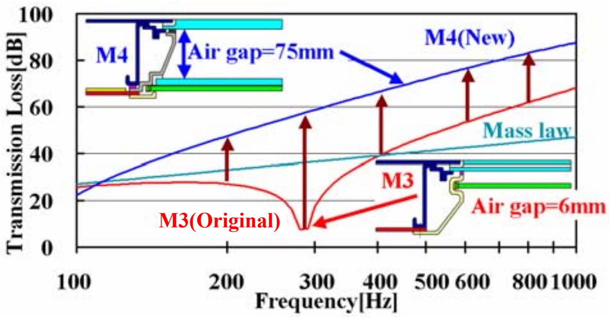


Fig.10 Calculated transmission loss of windows

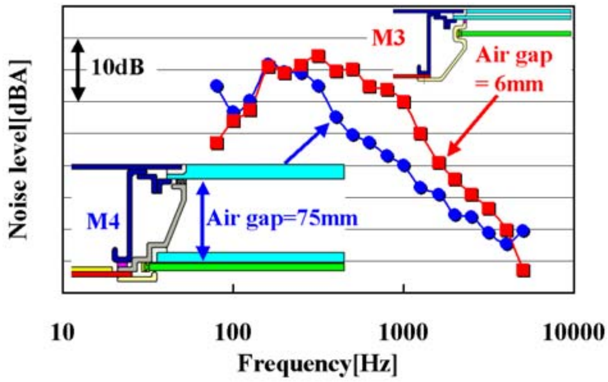


Fig.11 Comparison of noise in the cabin

3 Results of the 581km/h running test

On December 2, 2003, we established a new world speed record of the 581 km/h. We carried out this running test in order to evaluate reliability and performance margin of the JR-Maglev. The running time at speeds of 580 km/h or more was 5.6 seconds, and the distance was 903 m. The running tests at the speed of 581 km/h were conducted twice, and totally, 21 people of our project team rode at this test.

The vertical and lateral vibration amplitude of the displacement and the acceleration of the bogies and the cars at the speed of the 580 km/h was about the same as that of the 550 km/h. This result made it clear that the vehicle movement is very steady at the speed of the 580 km/h.

4 Conclusions

In this paper, the running test results of the new vehicle were discussed. The characteristics of levitation and lateral guidance were found to be good agreement with our calculation, and the improvement of aerodynamic characteristics were confirmed.

This year is the last year of the second phase of the running test on the Yamanashi Maglev Test Line. On the basis of these test data, we will make the specification and the design standard of the vehicle for the revenue service.

5 Acknowledgement

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