The status of development and running tests of Superconducting Maglev

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ABSTRACT: The Maglev Technological Practicality Evaluation Committee under the Japanese Ministry of Land, Infrastructure and Transport appreciated in March 2005 that “all the technologies of the Superconducting Maglev necessary for the future revenue service were established”. This appreciation means that the Superconducting Maglev technologies are ready for their applications to the potential revenue service. This paper reviews the running tests on the Yamanashi Maglev Test Line from April 1997.

1 OUTLINE OF THE TEST SCHEDULE

The running tests on the Yamanashi Maglev Test Line (YMTL) started in April 1997. In fiscal 1997-1999, we carried out the basic running tests and the general functional tests in order to verify the technical practicality as an ultra-high speed mass transport system. In the next five years, we carried out the evaluation of durability and reliability, the improvement of cost performance, and aerodynamic characteristics. With these test results for eight years in total, the Superconducting Maglev technology was evaluated overall. We have made the further improvements in core technologies and the further evaluation of durability since fiscal 2005. (Fig. 1)

The numbers show Japanese fiscal year.

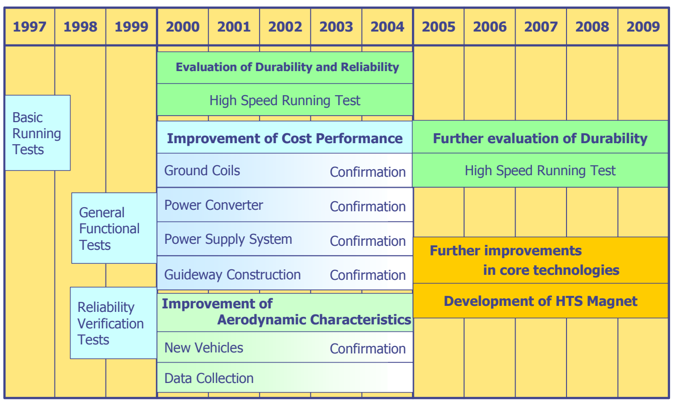

Figure 1: Running tests and development schedule.

2 TEST RESULTS

2.1 Basic Running Tests

We carried out basic running tests, such as wheel running tests, levitation running tests, speed increasing tests, and maximum speed verification tests step by step, confirming the running stability. They proceeded smoothly. The maximum speed exceeded 500 km/h in November 1997, and reached 550 km/h as the designed maximum speed in one month later of the year. We verified that the Superconducting Maglev had the stability performance of vehicles motion and braking and speed control.

2.2 General Functional Tests

In the general functional tests, we carried out substation cross-over tests, high-speed passing tests, multiple-train control tests, etc. Through these running tests at the speed of 500 km/h, we verified the stability performance of vehicles motion, braking and speed control of the Superconducting Maglev. The high-speed passing tests were carried out at the relative speed of 1,003 km/h. Moreover, we verified that it had the superior environmental capabilities along the YMTL. Besides, we carried out 5-car trainset running tests to verify the running stability of the intermediate cars in the longer trainset, and attained 552 km/h on the running tests with the 5-car trainset. As shown in Fig.1, we also executed high speed endurance running tests for reliability verification, confirmation tests of environmental friendliness and ride comfortable, and economical verification tests. At the end of fiscal 1999, the Maglev Technological Practicality Evaluation Committee under the Japanese Ministry of Land, Infrastructure and Transport appreciated that “the Superconducting Maglev technology has reached a stage that makes it a viable ultra-high speed mass transport system.” At the same time, the remaining technological assignments were pointed out by the Committee. In accordance with the indication by the Committee, we started technological development and running tests from 2000 based on the schedule shown as Fig. 1.

2.3 Improvement of Cost Performance

Through the running tests, we confirmed that the technological developments for the further cost reduction fulfill the designed performance and the estimated amount of cost reduction. The followings are 3 typical cases.

2.3.1 New sidewalls

We developed new type sidewalls, called “Self-standing guideway sidewalls” with a cross section of reverse T-shape. (Fig. 2) To meet the purpose of cost reduction, its weight was reduced in comparison with the former types of guideway, which brought easy handling and precise installation. For the further weight reductions, we developed a new type of guideway sidewall using ultra high strength fiber reinforced concrete (UFC), which contributed even to simplicity of substructure. (Fig. 3)

Figure 2: Self-standing guideway sidewall

Figure 3: Lightweight UFC guideway sidewall

2.3.2 New ground coils

We newly developed two types of ground coils. A single-layered propulsion coil is adopted in both coils, which is major alteration from the original double-layered coils. One is ”Integrated type coil” (Fig. 4), which consists of a propulsion coil and a levitation and guidance coil all in one. This type can reduce the number of coils compared with the conventional ones. The other is “Cable type propulsion coil” (Fig. 5), which aims to reduce manufacturing cost using power cable. We confirmed each performance of two type coils through the running tests. These coils can reduce not only the cost of manufacturing and installation, but also operation cost because of reducing eddy current drag by twisting the wire. And these coils are superior in reliability and maintainability compared to conventional types, by means of improving the mechanism of installation of coils and reducing the number of cable connection parts.

Figure 4: Integrated type coils

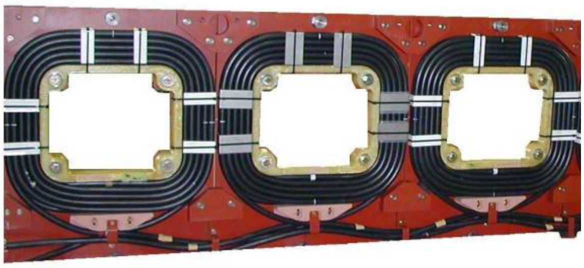

Figure 5: Cable type propulsion coils

2.3.3 New power converter

In order to reduce the cost of construction and operation, the new power inverter using IEGT (Injection Enhanced Gate Transistor) device was developed, which led to downsize of equipment and reduction of the electrical loss. It has been used since August 2002 on the YMTL. Its volume is half and the loss is one third compared with those of the conventional inverter using GTO device.

2.4 *Improvement of Aerodynamic Characteristics*

We developed two new vehicles for the YMTL, one is a leading car and the other is an intermediate car. For the further improvement of aerodynamic characteristics, the length of the leading car nose is stretched to 23 m from 9 m of that of the conventional ones. (Fig. 6) And new vehicles have the rectangular cross section in the lower part, in order to reduce aerodynamic phenomena.

Figure 6: Vehicles (left: conventional type, right: new type)

2.5 *Evaluation of Durability and Reliability*

We carried out high speed running tests to evaluate durability and reliability. Cumulative travel distance reached 428000 km at the end of fiscal 2004. Also average travel distance per year was about 70000 km, by conducting high speed running tests intensively. (Fig. 12) However some equipment – ground coils, trucks, etc – have difficulty in verifying longer durability during the running tests for eight years. So we confirmed that those equipment had durability by the bench tests that fulfilled the specification for the potential revenue service. Besides, we carried out the following running tests on durability and reliability.

2.5.1 *High Performance Verification Tests*

The travel distance per day in the potential revenue service is estimated to be about 2500 km. In order to verify durability and reliability, we carried out the continuous running test a day, attained 2876 km with 89 round trips on the YMTL. Moreover, the maximum speed attained 581.7 km/h exceeding the maximum designed speed on the YMTL and the potential maximum speed in the revenue service. It was verified that this system had enough capability in high speed operation. Besides we carried out further high-speed passing tests of 1026.3 km/h exceeding the potential passing speed for the revenue service and confirmed the stability of vehicle and ground equipment. Maximum speed trials and further high-speed passing tests were carried out twice each, which had recorded the same results, - the same maximum speed, the same passing speed and passing point. These results show that the control of this system is very exact. (Fig. 7, 8)

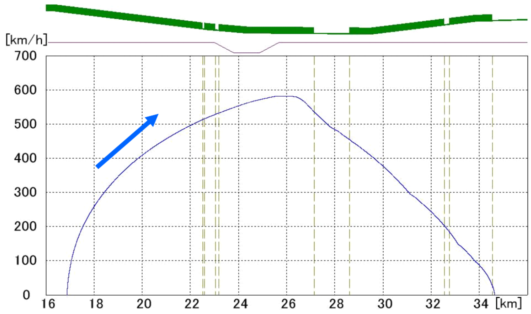

Figure 7: Running profile of Maximum Speed Trial Tests

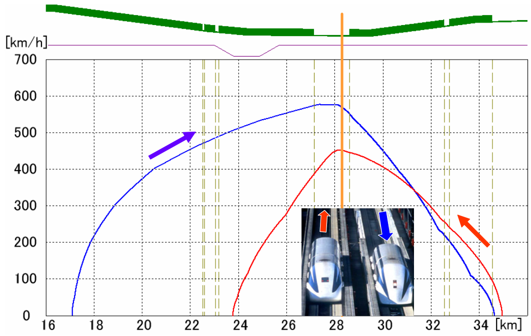

Figure 8: Running profile of Further High-speed Passing Tests

2.5.2 *Several Tests under abnormal conditions*

We conducted several tests under severe and abnormal conditions. The followings are some examples of them.

- Rescue operation tests, imitating a running mode of coupled two train set, one train under failure and the other under normal condition. (Fig. 9)
- Wheel and levitated running tests with backup wheel, compensating ongoing run in occasion of the tire punctured.
- Wheel and levitated running tests with emergency landing disk, compensating ongoing run in occasion of SCM failure.
- Lightning tests, confirming the electrical current path by lightning strike and influences on on-board control equipment. (Fig. 10)

Figure 9: Rescue Operation Tests

Figure 10: Lightning Tests

It was confirmed that there were no serious problems for the Superconducting Maglev through these tests.

2.6 Test Rides

The first test ride was held in May 1998. The number of passengers was more than 85,000 peoples, and cumulative days of the test rides were more than 300 at the end of fiscal 2004. We had no cancellation of test rides from the beginning. (Fig. 13)

3 OVERALL EVALUATION

In March 2005, the Maglev Technological Practicality Evaluation Committee under the Japanese Ministry of Land, Infrastructure and Transport appreciated that "all the technologies of Superconducting Maglev necessary for the future revenue service were established as a result of great progress in running tests and technological developments by the end of fiscal 2004." This appreciation means that Superconducting Maglev Technologies are ready for their application to the potential revenue service. These technical developments were partly subsidized by the Japanese government.

4 THE CURRENT STATUS OF DEVELOPMENT AND FOLLOWING VIEW

For the further evaluation of durability and the further improvements in core technologies of the Superconducting Maglev, we have been carrying out running tests on the YMTL. As the latter, CJRC carried out the first running tests of the Superconducting Maglev vehicle fitted with the HTS (High-Temperature Superconducting magnet). The HTS magnet using bismuth-based high-temperature superconducting wire enables stable superconductivity at -253℃, which is higher by 16℃ than the conventional LTS(Low-Temperature Superconducting) magnets. Through the running tests, it was verified that HTS magnets had applicability to the Superconducting Maglev system. (Fig. 11)

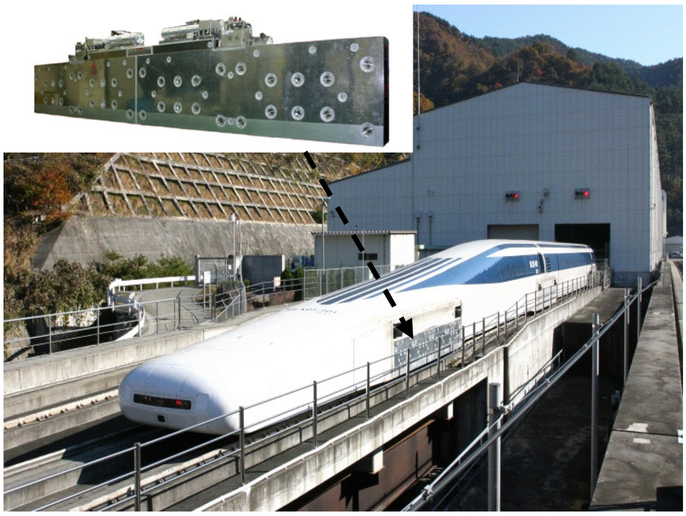

Figure 11: Running Tests with HTS magnet

Besides, CJRC has been carrying out the further improvement of the ride comfort, and the ground-coils for the further cost reduction, and running tests with novel train position detecting system without cross-inductive wire, etc. Also we have carried out the running tests for further evaluation of durability steadily. Cumulative travel distance reached 500000 km, the number of passengers reached 110000 peoples. (Fig. 12, 13)

We will continue to aim for further improvements in core technologies of the Superconducting Maglev, and to verify further evaluation of durability. Also we are going to make a study on a renewal and extension of the existing YMTL.

Running tests for the further evaluation of durability have been subsidized partly by the Japanese government since fiscal 2005.

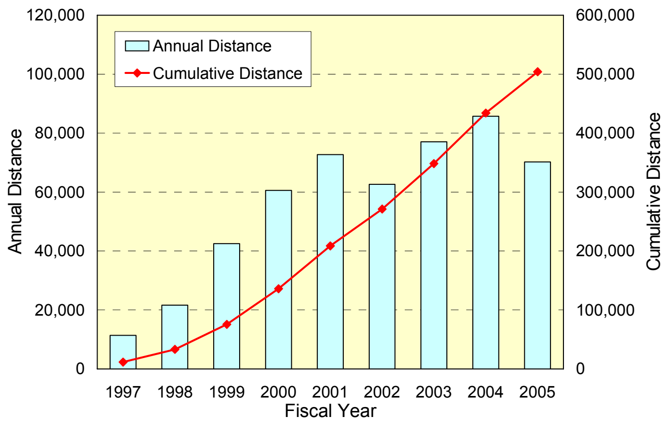

Figure 12: Progress of travel distance

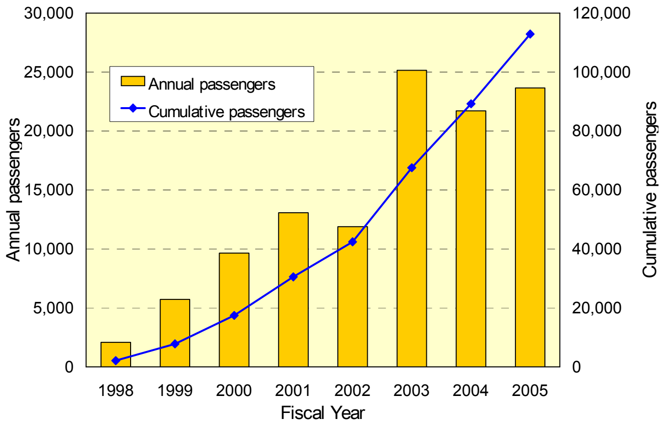

Figure 13: Progress of passengers

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