Outlook of the Superconducting Maglev

No. 136

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ABSTRACT: The Superconducting Maglev has been developed as an ultra-high speed mass transport system. It makes use of modern superconducting magnets (SCMs), which enable a large gap Electro-Dynamic Suspension and an efficient linear motor propulsion. Running tests have been conducted smoothly on the 18.4 km long Yamanashi Maglev Test Line since 1997 and reaped the harvests such as the maximum speed of 581km/h, relative speed of 1,026km/h on two trains passing test and on-board high temperature SCM running tests. In March 2005 the Committee under the Ministry of Land, Infrastructure and Transport appreciated that "all the technologies of the Superconducting Maglev necessary for the future revenue service were established." Based on this situation, JR Central has decided to expand the existing Test Line as well as renew the existing facilities and equipment into those of the future revenue service level. Furthermore, the Company has decided to promote the Tokaido Shinkansen Bypass project utilizing the Superconducting Maglev system.

1 SUPERCONDUCTING MAGLEV SYSTEM AND ITS CHARACTERISTICS

The Superconducting Maglev has been developed as an innovative transportation system for the next generation. It uses an Electro-Dynamic Suspension (EDS) system, and each truck of trains is equipped with superconducting magnets (SCMs) on both sides. Moving magnetic fields of the SCMs induce current in "8" figured levitation ground coils attached on the side walls of the U-shaped guide-way. The current produces the levitation force, interacting with the magnetic field of the SCMs. Corresponding levitation ground coils on both side walls are connected each other and produce the guiding force as SCMs pass by. EDS enables a large gap and stable running with no control. This system tends to have rather a low levitation/drag ratio, but the Superconducting Maglev has greatly improved the ratio, adopting a null-flux levitation and null-flux guidance system.

The Superconducting Maglev is driven by Linear Synchronous Motor (LSM). SCMs act as the field of the motor. The driving power is supplied to the propulsion ground coils, which are laid along the full length of the guide-way and divided into sections of a certain length. Only the section on which the train is running is fed from a substation. As the vehicle need not have driving equipment except SCMs, it is very light in weight and compact in spite of its high power.

2 HISTORY

Basic researches on ultra-high speed mass transport systems began in 1962. Among many candidates, Japanese National Railways（JNR） has chosen the Superconducting Maglev because of its high speed ability and great possibility. After fundamental tests, the 7 km long test track was constructed in Miyazaki, south west of Japan. The first test vehicle on the Miyazaki Test Track recorded 517 km/h in 1979. Then the test track was remodeled from the inverted-T shape cross section to the more practical U-shape, and the manned vehicle began to run in 1981. Basic tests with four types of test vehicle were conducted over the twenty-year period from its opening in 1977

to its closure in 1996. In this period, the development duties of the Superconducting Maglev were succeeded to Railway Technical Research Institute (RTRI) from JNR. These tests contributed to the progress of the Superconducting Maglev technologies. However, due to facility limitations at Miyazaki, such as a lack of tunnels, gradients and curves, it became necessary to construct a new full-scale test line to conduct tests under actual service line conditions.
The new Maglev test line was constructed with subsidies from the government, in Yamanashi, about 100km west of Tokyo. Thereafter, RTRI and JR Central commenced test operations at the new test line.

Figure 1. The first test vehicle on the Miyazaki Test Track "ML-500" recorded 517 km/h in 1979.

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3 YAMANASHI MAGLEV TEST LINE (YMTL)

The test line, which is double-tracked partially, is 18.4km long and has curved sections with a radius of 8,000m and a maximum gradient of 40‰. Approximately 87% is tunnels, and the longest open section is about 1.5 km in length. The Test Center and the power conversion substation are located here.

The vehicles (MLX) are of an articulated truck type having a truck at each end. This type was introduced in order to reduce the strength of the magnetic field in the cabins. This configuration also contributes to a decrease in the crosssectional area of the vehicle, which results in low aero drag force and reduction of the crosssectional area of tunnels. The vehicles are equipped with aerodynamic brakes and wheel disk brakes for emergency. Usually, trains are decelerated by electric regenerative brake. The SCM mounted on the vehicle contains four vertical superconducting coils and a helium tank with a builtin refrigerator.

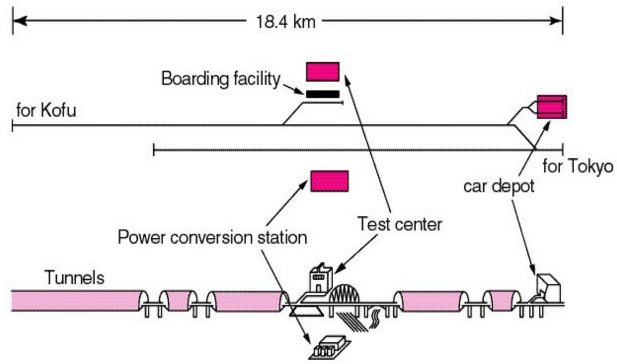

Figure 2. Configuration of the YMTL

Figure 3. The test vehicle MLX01

4 RUNNING TESTS

4.1 Outline of the Test Schedule

The running tests on the YMTL started in April 1997. In the first three years, the basic running tests and the general functional tests were carried out in order to verify the technical practicality as an ultra-high speed mass transport system. In the next five years, main themes of the running tests were the evaluation of durability and reliability, and the improvement of cost performance and aerodynamic characteristics. With these test results for eight years in total, the Superconducting Maglev technology was evaluated overall. Further improvements in core technologies and further evaluation of durability have been carried out since fiscal 2005.

4.2 Test Results

First, the basic running tests, such as wheel running tests, levitated running tests, speed increasing tests, and maximum speed verification tests, were carried out step by step, confirming the running stability. These tests proceeded smoothly. The maximum speed exceeded 500km/h in November 1997, and reached 550km/h as the designed maximum speed in the next month.

Next, the general functional tests, such as substation cross-over tests, high-speed passing tests and multiple-train control tests, were carried out. Through these running tests at the speed of 500km/h, the stability performance of vehicles motion, braking and speed control of the Superconducting Maglev were verified. The high-speed passing tests were carried out at the relative speed of up to 1,003km/h.

Figure 4. In the high-speed passing tests, relative speed of 1,003 km/h was recorded in 1999.

In the next five years, high speed running tests were continued to evaluate durability and reliability. Average travel distance per year was about 70,000km. The travel distance of 2,876km in one day was attained with 89 round trips on the YMTL. However, some equipment –ground coils, trucks – had difficulty in verifying longer durability during the running tests for eight years. The durability of such equipment was confirmed by the bench tests.

Through the running tests it was confirmed that the technological developments for the further cost reduction fulfilled the designed performance and the estimated amount of cost reduction.

Two new vehicles were developed for the YMTL. One was a leading car, and the other was an intermediate car. For the further improvement of aerodynamic characteristics, the length of the leading car nose was stretched. And new vehicles had the rectangular cross section in the lower part, in order to reduce aerodynamic phenomena.

Among these tests, 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. The top speed was recorded twice on the same day, and many researchers confirmed its ride quality. It was verified that this system had enough capability in high speed operation. Besides, further high-speed passing tests of 1026.3km/h were carried out, exceeding the potential passing speed for the revenue service. The stability of vehicle and ground equipment was confirmed.

In addition, several tests under severe and abnormal conditions were conducted, such as rescue operation tests and lightning tests. It was confirmed that there were no serious problems for the Superconducting Maglev.

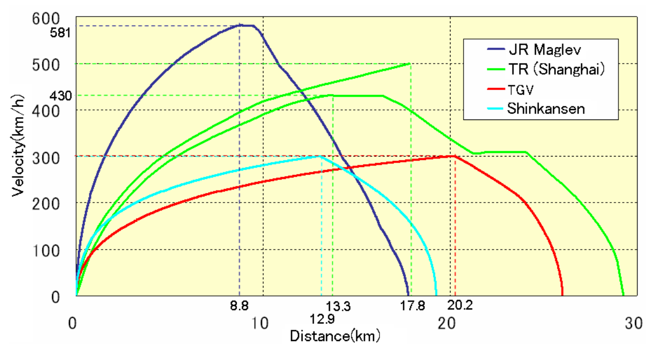

Figure 5. The running curve of the 581 km/h run of the Superconducting Maglev and the comparison with those of other high speed trains

Figure 6. The rescue operation test

5 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 the 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 the Superconducting Maglev Technologies are ready for their application to the potential revenue service.

6 CURRENT STATUS OF DEVELOPMENT

For the further evaluation of durability and the further improvements in core technologies of the Superconducting Maglev, running tests have been carried out on the YMTL. The cumulative travel distance exceeded 670,000km.

The High-Temperature Superconducting (HTS) magnet is a typical example of the improvement of core technologies. The HTS magnet using bismuth-based high-temperature super-conducting wire enables stable superconductivity at -253℃, which is higher by 16℃than the conventional Low-Temperature Superconducting (LTS) magnets. The running tests of the Superconducting Maglev vehicle fitted with the HTS magnet began in November 2006. The train exceeded 500 km/h on the first day of the HTS running tests. Through the running tests, it was verified that HTS magnets had applicability to the Superconducting Maglev system.

7 EXTENSION OF THE YMTL

The Superconducting Maglev technologies as well as their peripheral technologies have been progressing dramatically through the running tests for more than eleven years. Based on this current situation, JR Central has decided to expand the existing Test Line as well as renew specifications of the existing facilities and equipment into those of the future revenue service level. Through the expansion and renewal of the Test Line, the appropriateness of the upgraded specifications will be verified, responding to technical themes such as running tests for longer distance or through longer tunnels at the potential maximum cruising speed with longer train, and the maintenance system of the revenue service level will be established.

7.1 Main Features of Facility and Outline of New Experiments

- Expanding the existing 18.4km Test Line to 42.8km
- Upgrading the specifications of the ground coils and electrical facilities into those appropriate for longer trainsets
- Introducing fourteen new test vehicles and conducting running tests of longer trainsets at 500km/h

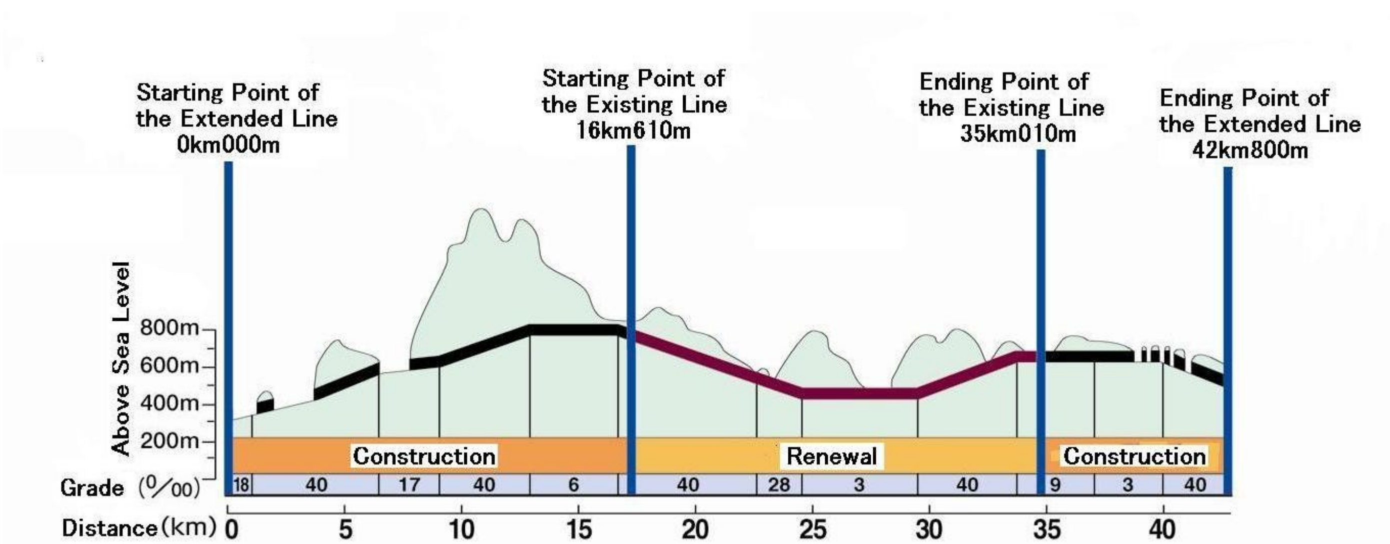

Figure 7. The outline of the extended YMTL

- Setting up more efficient maintenance system for the vehicles and ground facilities
- Building a full scale test facility which simulates a deep underground structures and conducting technical studies in such an environment

7.2 Project Costs

- Costs of ground facilities such as tunnels, elevated tracks, electric facilities and train depots : JPY 319 billion
- Cost for introduction of new test vehicles : JPY 36 billion

7.3 Project Schedule

- Project period for plan of renewal of facilities and equip-ment, extension of the Test Line and Running Test using renewed facilities : From FY 2006 to FY 2016
- Running test will start after the completion of Test Line extension in the end of FY 2013. The renewal of facilities and equipments continues until FY 2016.

8 PROMOTION OF THE TOKAIDO SHINKANSEN BYPASS

With respect to the Tokaido Shinkansen Bypass utilizing the Superconducting Maglev system, JR Central has deliberated on "promoting and realizing, on its own initiatives and as the first phase, the inauguration of commercial operation between the Tokyo Metropolitan and the Chukyo regions in 2025, the end of the first quarter of the twenty-first century." After making deliberations, the Board of Directors has concluded that the construction of the necessary line (the "Bypass") in this first phase as the "Chuo Shinkansen" under the Nationwide Shinkansen Railway Development Law on the premise that the Company would bear the cost for the project will contribute to a sustainable and stable management of the Company with payment of stable dividends. As a result, the Company has decided to take actions to promote the project on the basis of the above initiative on the premise that the Company would bear the cost for the project.

It is estimated that JR Central will spend approximately JPY5.1 trillion as construction costs and rolling stock expenses for approximately 290km line of the Super-conducting Maglev system, which are exclusive of the expenditure for intermediate stations and related costs that should be borne by local municipalities. After the inauguration of the Bypass, the Company will make investments for maintenance and renovation of facilities.

9 ACKNOWLEDGMENT

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10 REFERENCES

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