STATUS QUO OF RESEARCH AND DEVELOPMENT OF SUPERCONDUCTIVE MAGNETICALLY LEVITATED TRAIN

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1.INTRODUCTION

Recently, movement of people from one area to another has been increasing with vigorous economic activities in Japan.

Especially, the transportation connecting major cities on the line between Tokyo and Osaka, or transport of access to an airport located in the suburbs of a city, has been operated to full passenger capacity, and an enlargement of the capacity of transport has been demanded.

On account of an increased value of time due to an increased commuting distance, which is in turn due to a saving land price, time-saving is a strong demand from the commuters.

Therefore a system that can fill both the convenience of movement and the speedup must be realized.

After the success in SHINKANSEN, various efforts for speeding up have continuously been made in every field of railways.

Against this background, the development of a magnetically levitated train by superconductive magnets have been promoted to provide a transportation which aims at more speed and more comfort.

After the fundamental research and development of superconductive technology in our laboratories and running tests by some vehicles in MIYAZAKI Test Track, what remains today is to make the last tests of ascertaining the practical use.

2.DETAILS OF DEVELOPMENT

In order to create a railway system which would far exceed the SHINKANSEN in speed, it was necessary to seek a new one.

The magnetically levitated train was born in the course of groping after the successor to the SHINKANSEN.

The following are the reasons why it has been examined.

(1) For the train to run at a high speed beyond 500km/h, it is suspected that the conventional railway is limited by the adhesive force between rails and wheels.

(2) Adopting Linear Induction Motor (LIM) to be replaced later by Linear Synchronous Motor (LSM), will make it need-

less to mount a heavy motor on the vehicle.
(3) The height of levitation of about 100mm ensures this system against earthquake.
(4) Because of non-contact, it is advantageous in maintenance.
(5) Noise and ground vibration caused by train are smaller and they are favorable for the preservation of environment.

Around 1967, the first experimental facilities that had a small vehicle using permanent magnets and a short track with electromagnets were installed on the premises of the Railway Technical Research Institute (RTRI). It was the first step for the development. In 1972, marking the Railway Centennial in Japan, a vehicle of LIM system firstly succeeded in levitated running.

In order to prove the possibility of 500km/h running, a test track with a length of 7km was constructed in MIYAZAKI prefecture, south-west of Japan, about 1,000km away from TOKYO, in 1975. (Figure 1)

In December 1979, an unmanned vehicle named ML-500 attained a maximum speed record of 517km/h surpassing the target speed, which demonstrates the feasibility of high speed running.

Subsequently, it was found that the straddled type vehicle had to be changed into a more practical box type one to secure a room for passengers, and the inverted-T shaped guideway was transformed into U shape. The manned vehicle named MLU001 after that transformation successfully attained a speed of 400.8km/h in 1987.

And MLU002 which was the latest vehicle debuted in the same year, the traverser-type turnout was constructed in 1990, and its durability tests, which are indispensable to increase traffic capacity, have been done (Photo 1).

3.COMPARISON OF MAGNETICALLY LEVITATED VEHICLE

The magnetically levitated train system HSST of Japan and TRANSRAPID of Germany are levitated by attractive force using electromagnets, but the JR type levitated train uses repulsive force with superconductive magnets.

In MIYAZAKI Test Track, we have had the facing levitation method with the ground coils for levitation arranged on the slab of viaduct. But it was decided to change the levitation method from the facing to the side-wall type to reduce the magnetic drag. In the side-wall levitation method, a ground coil for levitation ("8"-figured coil) formed by invertedly connecting the small upper one with the lower one is set up on the side-wall of the guideway (Figure 2).

Though the magnetic drag which influences electric consumption in running increases at low speed, the side-wall system, which is superior in efficiency of levitation force to the facing one, may reduce the electric drag.

Besides, there is the merit that the high voltage at null-flux cables will be cut down by using the side-wall levitation coils for lateral guidance of the vehicle instead of as coils for propulsion.

The side-wall levitation method has already been set up on some sections in MIYAZAKI Test Track, and the data about the vehicle motion, riding comfort, etc. were collected.

This will be adopted in all sections of the newly constructed test track in YAMANASHI prefecture.

4.BRIEF DESCRIPTION OF NEWLY CONSTRUCTED TEST TRACK

In order to put the vehicle to more practical use as means of railway, a new test track which has the sufficient facilities to promote the technological development related to the magnetically levitated train will be needed in future. This is due to the facts that MIYAZAKI Test Track in only 7km in length with a single track and the structures consist of only viaducts and bridges, and that it is impossible to carry out a running test in tunnel sections.

Japan Ministry of Transport (MOT) made investigations and studies on the site suited for construction of a new test track and the step of pursuing the technological development for its realization.

Meanwhile, MOT set up an internal committee called "The Superconductive Magnetically Levitated Train Study Committee" (Chairman; Prof. Dr. Eng. Yoshiji MATSUMOTO, Science University of TOKYO) in 1988.

The requirements for the new test track agreed upon by the committee are as follows;

(1) There shall be a continuous straight section.
(2) There shall be a curve.
(3) There shall be a steep slope section.
(4) There shall be structures such as tunnels and viaducts.
(5) Besides fulfilling the above requirements, the test track shall have an overall length of some 40km or so.

After the discussion being made concerning the test track construction site, the committee selected YAMANASHI prefecture as the best one from the view point of feasibility of achieving the test objects, effective use in future and obtaining the cooperation of local authority concerned.

The plan for development of fundamental technology and the plan of YAMANASHI Test Track construction are approved by the Minister of Transport in June 1990, and these plans are being pursued.

The YAMANASHI Test Track (Figure 3) has a length of 42.8km including about 35km length of tunnel sections, partially with double tracks. And it has some sections with maximum gradient of 40 permillage (4 percent), and with minimum radius of curvature of 8,000m. The distance between the centers of tracks is 5.8m. The construction cost amounts to 263 billion yen.

The development plan is scheduled : the test for practical use in YAMANASHI Test Track, fundamental test in MIYAZAKI Test Track and RTRI's laboratories.

The construction was commenced in fiscal 1990. The test will be started from fiscal 1994 in the middle of the construction, and a prospect for the technological development including the technical issues is to be formed by fiscal 1997.

Two trains will run at a speed of about 500km/h (maximum speed of 550km/h) on the test track consisting of the curve section, the steep slope section, the tunnel section, the turnout, and so on.

Besides, the synthetic tests, which involve various fields such as vehicles, substation, train control system, guideway, environment, etc. shall be done.

The following are main items to be tested;

(1) Stable run at 500km/h with safety and comfort.
(2) Reliability and durability of vehicles including superconductive magnets and ground facilities.
(3) Structural standards specifying a minimum radius of curvature, the steepest gradient, etc.
(4) Distance between both guideways taking account of two trains passing each other.
(5) Vehicle performance related to tunnel cross section and to the pressure fluctuation in a tunnel.
(6) Turnout performance.
(7) Control system between substations.
(8) Multiple train operation control system.
(9) Safety operation system.
(10) Environmental preservation.
(11) Technical standards on maintenance.
(12) Investigation of cost performance, and grasp of construction and operation cost.

5.TECHNICAL ISSUES IN THE SUPERCONDUCTIVE MAGNETICALLY LEVITATED TRAIN

Some technical issues about the superconductive magnetically levitated train in practical use are as follows.

5.1 Energy consumption

Because of an increased aerodynamic force in proportion to the square of the velocity, more energy is consumed as the train runs faster.

Comparison in energy consumption between transportation systems should be made by total amount of energy consumed through their operation over the distance from the starting point to the terminal one. If the magnetically levitated train runs between TOKYO and OSAKA at a maximum speed of 500km/h, the electric power consumption can be estimated at about 90Wh(Watt hour) per kilometer per passenger. This is about three times as much as the amount of electric power consumption of TOKAIDO-SHINKANSEN which is 30Wh per kilometer per passenger at a maximum speed of 220km/h running.

In order to compare the energy consumption of the superconductive magnetically levitated train with jet plane's, the electric power consumption of the former is to be converted into calories, so it could be compared with the fuel consumption of jet plane. Then, the calorie consumption of the magnetically levitated train can be estimated at 220kcal. per kilometer per passenger. According to the data reported by MOT Japan the calorie consumption of jet plane (Boeing 747-SR) is 400kcal. and so this is nearly twice as much as the former.

Consequently, it can be said that the superconductive magnetically levitated train would be a kind of energy-saving transportation in spite of its super high speed running.

5.2 Effect of magnetism on human body

In developing the magnetically levitated train with superconductive magnets, issue of magnetism has been often talked about.

There are two kinds of magnetic fields, that is, a steady-state magnetic field having constant magnetic force and a fluctuating magnetic field where the magnetic force alternates. Running of magnetically levitated train generates the alternating magnetic fields along the guideways.

Recently, some bioelectromangetics researchers pointed out the effect of alternating magnetic fields on organism. But there are few papers which make clear the effect of them on human body. RTRI researchers have studied the mechanism of bioelectromagnetics in experiments on not only mammals such as rats or mice, but on fruit flies.

It was necessary to provide the provisional guidelines for the alternating magnetic fields in YAMANASHI Test Track. No safety guidance on standard for extra low frequency (ELF) magnetic fields has been available in Japan.

Actually, the value of the fluctuating magnetic field on the ground under the viaduct which is 8m in height in MIYAZAKI Test Track has induction of about 0.5 gauss for very short time while the train passed there. This is much the same as the magnetic field of the earth.

On the contrary, there is a steady state magnetic field for the passengers inside of the vehicle. But, it is possible to avoid its effect by taking measures on the floor of commercial train such as the superconductive magnets being arranged remote from the seats and the shielding against magnetism strengthened.

Moreover, the safety for workers near the superconductive magnets in the car shed is ensured by the RTRI original standard based on the work referring to the relation between the strength of magnetic fields and the time of duration.

5.3 Noise

The noise, one of the problems when the train is running at high speed, is a kind of problems to be settled above all things. The running of the contact-free magnetically levitated train has no friction noise such as rolling friction noise caused between the rails and wheels or sliding friction noise between the overhead trolley and pantograph.

It has mainly the aerodynamic noise caused by the train hurtling through the air, and so the tone quality is completely different from the one of the conventional railway. The measured value of noise caused by vehicle MLU002 in running at the speed of 300km/h in MIYAZAKI Test Track was 79dB at peak level at the observed point, which had no structure and was 25m far from the elevated structure without noise barrier which was 8m in height and located 1.2m above the ground.

The height and width of the vehicle to be used in YAMANASHI Test Track will be designed smaller than the one in MIYAZAKI Test Track (Table 1).

The noise is mainly dependent on the vehicle when it runs in the guideways. The value of noise in YAMANASHI Test Track will be expected to be made about 10dB lower than that of MIYAZAKI Test Track by the methods of smoothing the flanks, redesigning the front nose of the new vehicle and flattening the surface of the ground coils.

5.4 Ground vibration caused by vehicle

The weight of the magnetically levitated train is half that of SHINKANSEN's, and the weight of the train is distributed over the guideways in running because of its contact-free system.

Therefore, a problem in ground vibration by the superconductive magnetically levitated train is not more serious than that of conventional railway system.

6. CONCLUSIONS

On the 3rd October of last year, the test vehicle of

MLU002 burned down in an accident in MIYAZAKI Test Track.

It was suspected that one of the wheel tires blew out, and the rotation being locked by something, an excessive friction between the reinforced wire of tire and the concrete slab occurred. It was not enough to take measures against fire by means of reducing the weight.

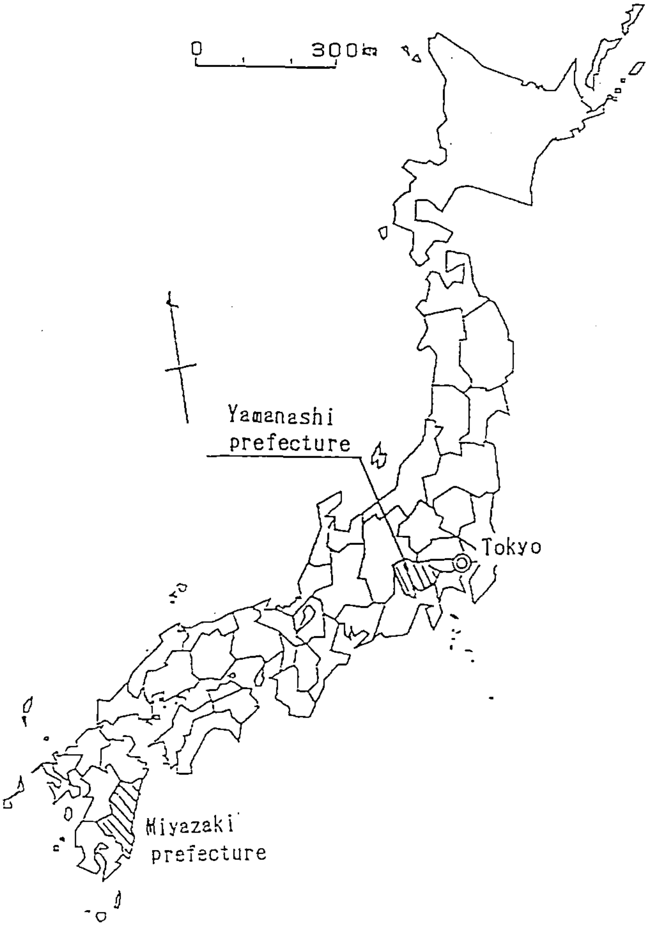
Therefore, it was speculated that the vehicle as a whole was damaged by fire quickly. The structures of the new vehicle will be made of incombustible or of uninflammable materials.

The subjects still remain to be studied such as the pursuit of safety, improvement in reliability, environmental preservation, etc.

However, in 1990, RTRI,the Japan Railway Construction Public Corporation, and the Central Japan Railway Company formed a consortium to construct the Yamanashi Test Track for the final stage of develop of this system.

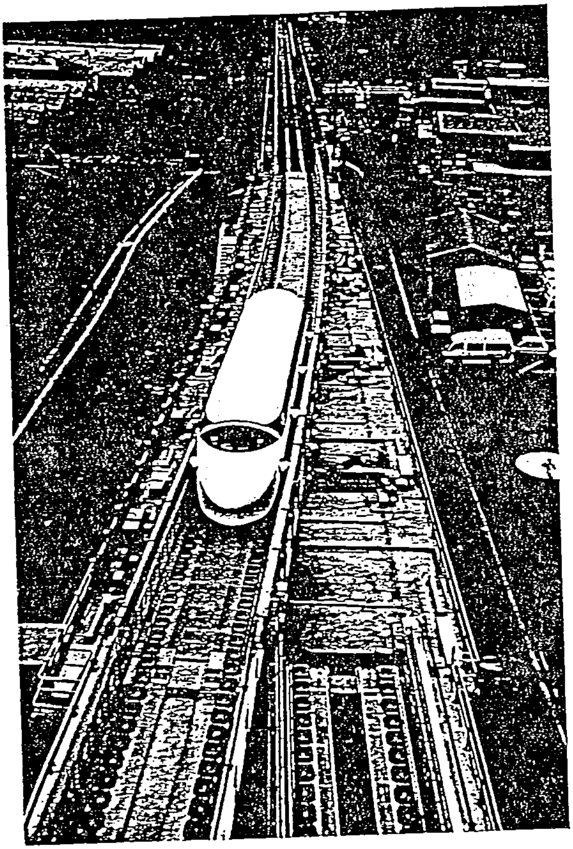
Then, after completing the construction of Yamanashi Test Track as early as possible and after making all examinations successfully, we are determined to develop the superconductive magnetically levitated train in time for an early part of 21st century.

Figure 1



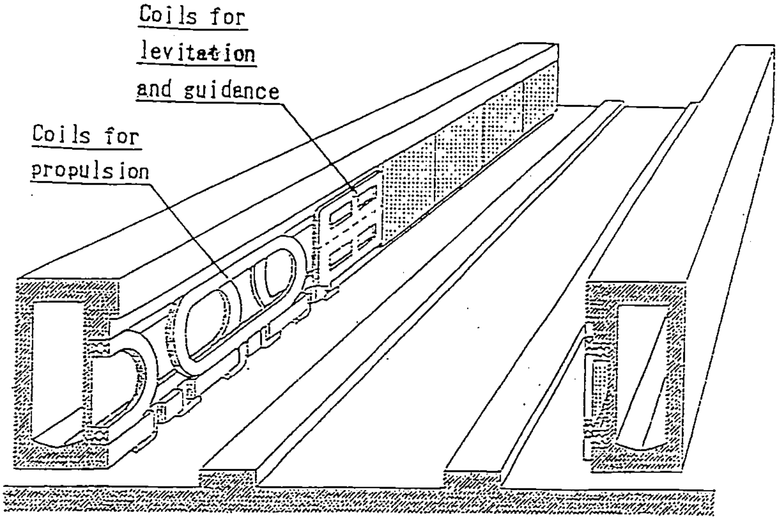
Map of JAPAN

Photo 1



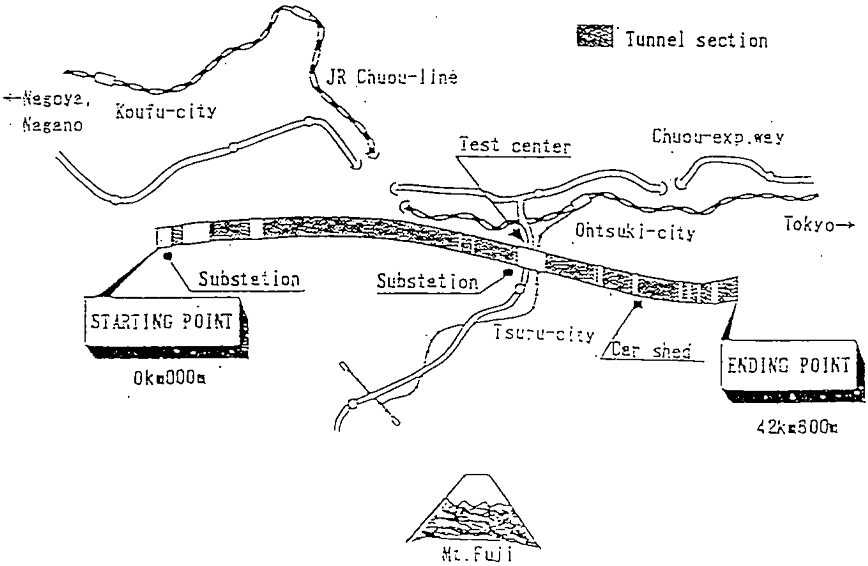
Traverser-type turnout

Figure 2



Side-wall levitation method guideway

Figure 3



YAMANASHI Test Track

Table 1

	Miyazaki(MLU002)	Yamanashi Vehicle
Height (m)	3.70	3.32
Wide (m)	3.00	2.90
cross sectional erea (m^2)	10.3	8.9

Vehicle of YAMANASHI and MIYAZAKI's