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Vehicles for superconducting Maglev system on Yamanashi test line

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Abstract

A superconductive magnetic levitation (Maglev) system in Japan has been developed to an extent that basic technology is established on Miyazaki Maglev Test Track and now for the purpose of practical technology development the construction of Yamanashi Test Line is underway. Yamanashi Test Line is the last stage for making sure the possibility of commercialization of Maglev system. We decided configuration of vehicles which will run at a speed of over 500 km/h on Yamanashi Test Line and have already started a detailed design of vehicles. This paper describes the lightweight bodies, lightened bogies for vehicles of Yamanashi Test Line.

1. Introduction

Development of a superconductive magnetic levitation (Maglev) system in Japan was started in 1962 by Japanese National Railways (J.N.R.). That was two years before Tokaido Shinkansen Line between Tokyo and Osaka went into a revenue service.

We decided at once that the next new high–speed train should be Maglev System. Then we began to study Maglev System and at the same time to design vehicles for Maglev System.

In 1972 an experimental vehicle ML100 of superconductive Maglev system succeeded for the first time in a levitated running on the Experimental Short Test Track. In 1975 ML100A succeeded in a perfect non–contact run by SCM.

In 1977 the test run of ML500 took place on Miyazaki Test Track of 7 km length. ML500 attained a maximum speed record of 517 km/h in 1979. We have made many experiments since 1979 on Miyazaki Test Track by several different types of vehicles, which are ML500, ML500R, MLU001, MLU002 and MLU002N. And over 10,000 people including general visitors tried a ride on the Maglev Vehicles MLU001 and MLU002. The experimental and trial run of manned vehicles proved the safety of Maglev System and Vehicles. On the basis of those experimental results we have developed and designed Maglev Vehicles for Yamanashi Test Line since 1990. Right now we decided configu–

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rations of Vehicles on the Yamanashi Test Line and have already started a detailed design of them.

Here are outlined the Vehicles for Maglev on Yamanashi Test Line and details of development of the experimental vehicles for Maglev on Miyazaki Test Track.

2. Details of Development of the Vehicles for Maglev System

2.1 ML100

ML100 which was the first experimental small vehicle for superconducting Maglev system debuted in 1972 (Fig.1). It had 4 seats. In 1972 ML100 succeeded in levitated running at a speed of 60 km/h on the Experimental Short Test Track in J.N.R.'s Kunitachi Laboratory. In 1975 ML100A succeeded in levitated perfect non-contact run.

The results of repeated experiments by ML100 series made us confident of the possibility of 500 km/h running. That was the first step in Maglev system.

2.2 ML500

In 1975 we constructed Miyazaki Test Track with a length of 7 km. In 1977 ML500 was fabricated for the new test track with inverted-T shaped guideway (Fig.2). ML500 attained a maximum speed record of 517 km/h run on 21 December 1979.

We could succeed in the experimental 500 km/h running only in 7 years after taking the first step.

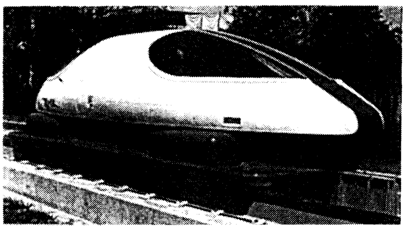

Fig.1. ML100

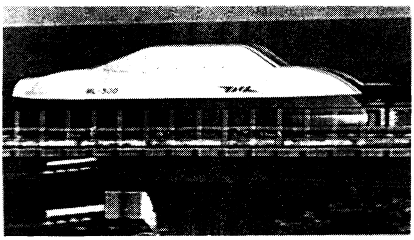

Fig.2. ML500

2.3 MLU001

In 1980 Miyazaki Test Track was reconstructed. The invert-T shaped guideway was transformed into U-shaped. From 1980 to 1982 the manned vehicle MLU001 was fabricated for the U-shaped guideway. MLU001 is a 3-car unit (Fig.3). In 1986 MLU001 of 3-car unit attained a speed of 352.4 km/h. In 1987 MLU001 of 2-car unit attained a maximum speed of 405.3 km/h run unmanned and it attained a speed of 400.8 km/h run manned. The trial ride on MLU001 carried about 1,200 people in total.

MLU001 also had an experiment of an aerodynamic brake system which we had developed to secure a reliable emergency braking at a speed of over 350km/h (Fig.4).

2.4 MLU002

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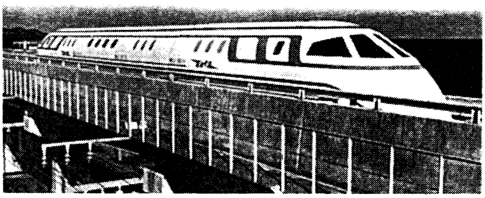

Fig.3. MLU001

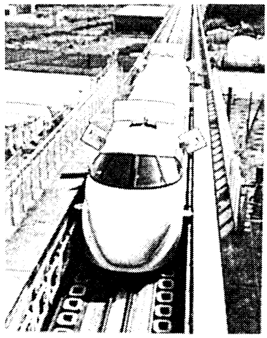

Fig.4. Experiment of aerodynamic brake on MLU001

In March 1987 the construction of MLU002 was finished (Fig.5). The coil distribution was changed to a concentration style from a dispersion style.

In December 1989 MLU002 attained a speed of 394 km/h run. It had 44 seats for passengers. About 9,500 visitors tried a ride on MLU002. The number of trial riders of MLU001 and MLU002 on Miyazaki Test Track including general visitors amounted to over 10,000. This testified to the safety of the vehicle for Maglev system.

But unfortunately we lost MLU002 by a fire accident on 3 October 1991.

2.5 MLU002N

In December 1992 the latest vehicle named MLU002N debuted on Miyazaki Test Track (Fig.6). We designed it taking lessons from the fire accident. We chose kinds of material, structure of body, bogies and equipment for fire-protection. For example, all-aluminum body instead of FRP'use, non-combustible material in the body, new aluminum wheels without using magnesium alloy, safety tires, use of fire-resistant hydraulic oil, fire extinguishing appliances, fire warning systems, and so on.

MLU002N has a new pair of aerodynamic brakes as emergency brake system and 12 seats for passengers. In order to provide the better riding comfort for the magnetic cushion each bogie has two different types of elastic support of SCM.

MLU002N's test runs started in January 1993. On 24 February we succeeded in running at the highest speed of 431 km/h. We continue to test running now.

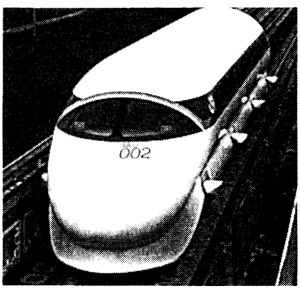

Fig.5. MLU002

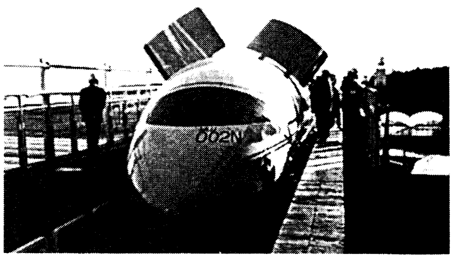

Fig.6. MLU002N

3. Vehicles on Yamanashi Test Line

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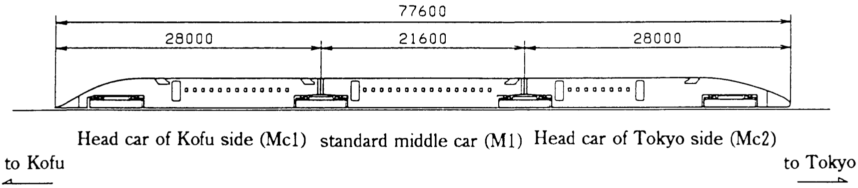

Fig. 7. Outline of Yamanashi Maglev Train

3.1 Outline of Vehicles

Yamanashi Test Line is the last stage for making sure the possibility of commercialization of Maglev system. Therefore we have to bear the revenue service in mind in designing new vehicles. For example, seating capacity, service equipment, high riding comfort, etc.

There are two train sets which will run at a speed of over 500 km/h (maximum speed of 550 km/h) on Yamanashi Test Line, one of which is a 3–car unit and the other a 5–car unit. Each train consists of articulated bogies (Fig.7).

Main conception of vehicle design is described as follows.

(a) Vehicles run at over 500 km/h high speed and top priority in design will be given to safety and reliability.

(b) As the train control is based upon ground primary control system, vehicles must be designed from a fail–safe point of view. Especially information transmitting devices between ground and vehicles, on–board control system and on–board brake system will be designed with emphasis on safety.

(c) Vehicles will be specified giving priority to environment (noise, magnetism and so on) and habitability (riding com fort, change of pressure and so on).

(d) For getting necessary data in limited period, vehicles must be designed and fabricated so that efficient test runs can be scheduled.

3.2 Trial Lightweight Bodies

The bodies must have their weight reduced as much as possible and at the same time must have enough rigidity and airtightness for the riding comfort. The total weight of each body including all equipment is limited to less than 13 tons for a middle–car or 17 tons for a head car.

We have already developed 4 types of trial lightweight bodies since 1989. Here is the present status of R&D.

(1) H1 type body

In 1989 H1 type body named H1–body was fabricated, the length of which was 21.0 meters (Fig.8). It was the first trial body for the commercialized Maglev vehicle. It is made of aluminum and steel. The main part of body is constituted of aluminum. Outside shell is made of aluminum shapes. And frames are made of machined aluminum plates. They are joined by spot–welding or riveting. Both ends of body are constituted of steel, because it is effective for shielding a passenger room from magnetic influence of SCM. The main body and the end body are joined by special riveting.

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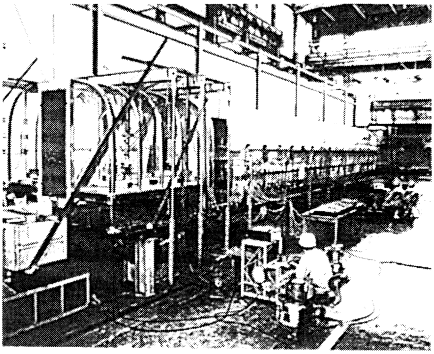


Fig.8. The experiment of H1-body

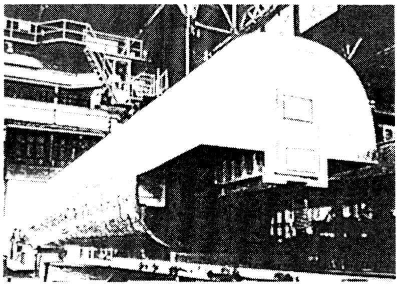


Fig. 9. H2-body

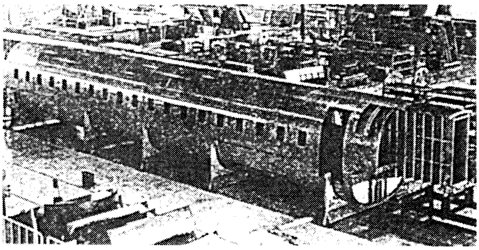


Fig.10. H3-body

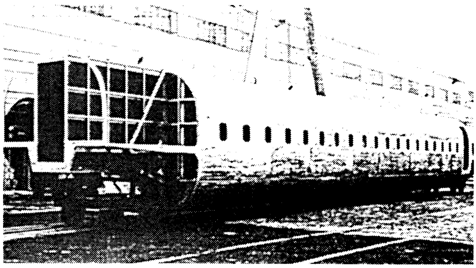


Fig.11. H4-body

(2) H2 type body
H1-body was still in the experimental stage of developing a lightweight body. In 1990 H2 type body named H2-body was fabricated, the length of which was 23.7 meters, that is 2.7 meters longer than H1-body. It is called "long-body", which was the first trial long-body of Maglev vehicle (Fig.9).

It is made of aluminum and steel, the same as H1-body. The main part of body is constituted of aluminum plates. Outside shells are thin aluminum plates. Stringers and frames are machined aluminum plates. They are joined by all spot-welding. Both ends of body are constituted of steel for the same reason as H1-body. The main body and the end body are joined by special riveting.

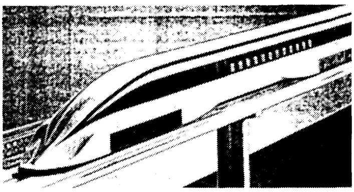
(3) H3 type body
In 1991 H3 type body named H3-body was fabricated, length of which was as long as "long-body" (Fig.10). It is made of duralumin used in airplane and steel. The main part of body is constituted of duralumin. Outside shells are thin duralumin plates. Stringers and frames are machined duralumin plates. They are joined by all riveting. Both ends of body are constituted of steel and partly duralumin. The main body and the end body are joined by special riveting.

(4) H4 type body
In 1992 H4 type body named H4-body was fabricated, the same as "long-body"(Fig.11). It is made of brazed aluminum honeycomb panels and steel.

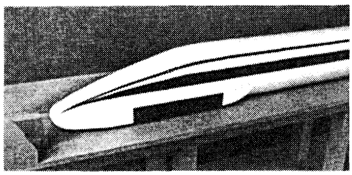
The main part of the body is constituted of all brazed aluminum honeycomb panels. Outside shells are the built-in aluminum honeycomb panels with aluminum frames. Therefore not any stringers and frames are seen inside. They are joined by welding. Both ends of body are constituted of steel. The main body and the end body are joined by special riveting.

3.3 Nose-shape of Head Cars

Vehicles for superconducting Maglev on Yamanashi Test Line have two types of nose-shape (Fig.12). One type is called "Double Cusp" style and the other is called "Aero-wedge" style. Both of them are superior in aerodynamic performance, especially in aerodynamic drag, aerodynamic noise and micro-pressure waves of tunnel. We designed them based on the results of CFD analysis and some experiments in the wind tunnel.



"Double Cusp" style



"Aero-wedge" style

Fig.12. Nose-shape of head cars

3.4 Bogie Systems

The bogies are also lightened. Additionally one type of them has to suspend the SCM elastically by air-springs for the riding comfort. If the SCM is quenched, the rubber tires must be able to run long distance at high speeds. So we need tough and safe tires. The on-board contact-free power-collection utilizes the electromagnetic inductance between the SCM aboard the vehicle and the levitation coils on ground.

Under such conditions we have been developing the new Maglev bogies.

(1) Elastic Support of SCM

The bogies for Yamanashi Vehicles will have the elastic support system of SCM to provide the riding comfort for the magnetic cushion. The conventional bogie frame consisted of cross-beams and side-beams connected with SCM directly and rigidly (Fig.13).

The elastic support of SCM called "Double Bogie Frame" system uses two different frames, one of which is intermediate bogie frame connecting the body to 2 air-springs, and the other is SCM supporting frame connecting the intermediate bogie frame to another 4 air-suspension (Fig.14).

We are going to design Double Bogie Frame referring to the experimental result at Miyazaki Test Track using MLU002N.

(2) Lightweight Bogie Frame

The total weight of each bogie is limited to less than 6.5 tons including SCM and all equipment. But it is difficult to reduce the weight of bogie frame,

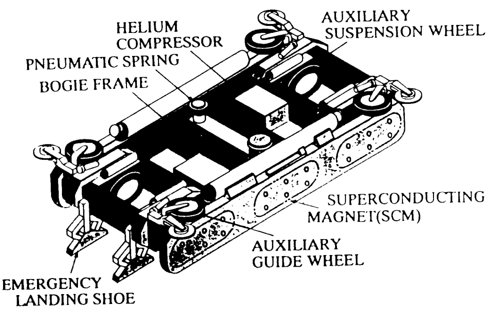


Fig.13. Conventional Bogie of MLU002

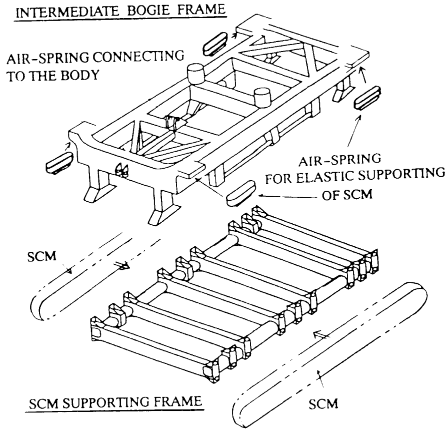


Fig.14. Bogie of elastic support of SCM ("Double Bogie Frame" system)

because the structure of bogie frame is so simple that there is no room for further reduction.

The conventional bogie frame was made of aluminum plates and shapes. We have made R&D about material and constitution of frame, whose candidates are all FRP shapes, aluminum honeycomb panels, all riveting structure without welding, and so on.

We have already started a detailed design of bogies for Yamanashi Vehicles.

3.5 Head Car of Tokyo Side (Mc2) and Standard Middle Car (M1)

"Mc2" is a head car of Tokyo side and "M1" is a standard middle car of the first train set on Yamanashi Test Line (Fig.15, Fig.16). Mc2 has an "Aero-wedge" style nose-shape. Mc2 has 30 seats for passengers and M1 has only a space of 62 seats for passengers, because Mc2 is one of the trial riding cars and M1 is the only test car.

A half of Mc2 body is a passenger room and the other half is an engine room in which there are a main battery, a gas turbine generator, a DC/DC converter, helium gas buffer tanks, air tanks, an air compressor, many electric equipment, and so on. Both cars carry an aerodynamic brake system, ventilation facilities and an air conditioning equipment.

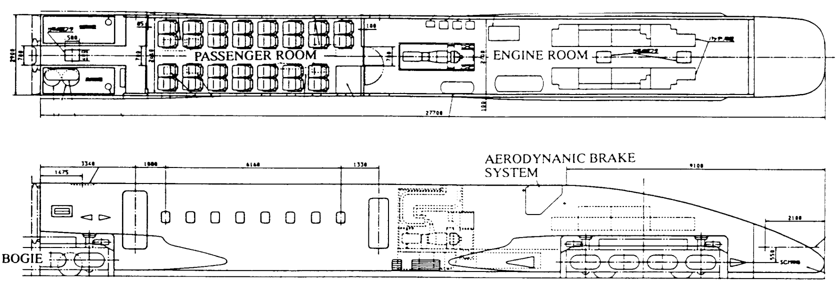


Fig.15. Draft of head car of Tokyo side (Mc2)

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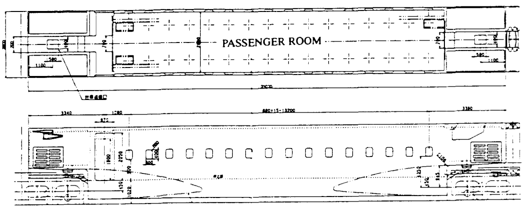

Fig.16. Draft of standard middle car (M1)

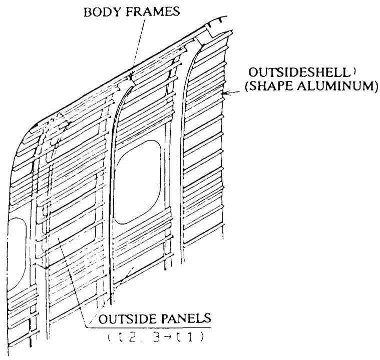

Fig.17. Main body structure of Mc2

The main body structure of Mc2 is based on the design of H1-body. The body structure of M1 is based on the design of H2-body. The main material of both body is aluminum alloy (Fig.17).

3.6 Other Components

There are additionally many special components to be
installed on vehicles for superconducting Maglev on Yamanashi Test Line. For example, body suspensions, support wheels, guide wheels, fire warning and extinguish system, and so on.

Regrettably space limit does not allow us to introduce many other pieces of equipment which we have developed so far.

4. Closing Remarks

We gave an outline of vehicles for Maglev system on Miyazaki Test Track and Yamanashi Test Line which we are developing right now.

Meanwhile the ground installations such as tunnels, power converters, ground coils, are now under construction in Yamanashi Prefecture. Although the orchestration of all the facilities, and new systems including vehicles are essential, intricate point, we are confident in the success of Maglev System on Yamanashi Test Line.

The development of the superconducting maglev system has been financially supported by the Ministry of Transport of Japan.

And some results have been obtained by Central Japan Railway Co. and cooperative makers of cars and equipment.

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