THE FIRST HSST MAGLEV COMMERCIAL TRAIN IN JAPAN

Yoshihide Yasuda*[1], Masaaki Fujino*[1], Masao Tanaka*[1]
and Syunzo Ishimoto*[2]
*[1] *Chubu HSST Development Corporation, Chubu.Hsst@mix.meitetsu.co.jp*
*[2] *Aichi Kosoku Kotsu Corporation, ishimoto@linimo.jp*

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Abstract
The first HSST (High Speed Surface Transport) Maglev commercial train in Japan, which is levitated by the attractive force of normal conductive magnets and propelled by Linear Induction Motor (LIM), will start its revenue service on the Tobu Kyuryo Line in the northeastern suburbs of Nagoya city in Spring , 2005.

1. Introduction

The East Hillside Line in Nagoya (also called as Tobu Kyuryo Line) is the first commercial application of the magnetic levitation system for HSST in Japan, currently under construction aimed at the grand opening of the World Exposition, "Aichi Expo. 2005" scheduled for the coming March in 2005. This report summarizes the system description of the HSST system including its peculiar guideway and vehicle system which is very different from the conventional railroad vehicles and also its latest construction status including design concept of Linimo vehicle and its guideway for Tobu Kyuuryo Line.
The HSST (High Speed Surface Transport) Maglev technology is based on a normal conductive system levitated by the attractive force of magnets and propelled by Linear Induction Motor (LIM) without wheels. It will be used on the Tobu Kyuryo Line in the northeastern suburbs of Nagoya city in Japan. That line construction is scheduled for completion by this autumn followed by about four months vehicle performance verification tests. This line will connect the town of Fujigaoka, a highly developed urbanized area, to the town of Yakusa, passing through a number of developing suburbs. It will take about 15 minutes to travel the entire 9 kilometer-long guide-ways. The line will reach a maximum system speed of 100 km/hr with a passenger forecast of about 30,000 per day.

2. Development History of HSST

These HSST Maglev train vehicles are manufactured by Chubu HSST Maglev technology which was approved and being constructed under the Japanese standards, codes, and guidelines.
Concerning its development history, development of the HSST magnetically levitated train system began nearly thirty years ago by Japan Airlines Co.

Photo-1 HSST -100 TKL Linimo train in depot

After Yokohama Exposition in 1989, the Chubu HSST Development Corporation, sponsored by the Nagoya Railroad Group, Aichi Prefecture and HSST Corporation, was established to further develop the first fully commercial practical version of the HSST train. Thereafter, CHSST constructed a new 1.5 km test track at Oe in Nagoya where full-scale commercial application testing of HSST's current generation vehicles, the short-type 100S, and long-type 100L, had taken place till 2003 March including testing the newly manufactured prototype of TKL "Linimo" train. After that in February 2000, a quasi-public corporation named "Aichi Kosoku Kotsu (AKK) Co." was established in order to construct and operate TKL line and is working at present for that purpose.

3. The Outline of Tobu-Kyuryo Line

The Tobu Kyuryo Line will be a middle -capacity connector line that will connect a terminal of the Nagoya subway in the eastern area of downtown Nagoya, Fujigaoka station, to one of the Aichi Circle Line stations adjacent to the Exposition site, Yakusa station. The total estimated project budget of the Tobu Kyuryo Line is 100,000 million yen (US$770 million).
Route; From Fujigaoka (Eastern terminal of Nagoya Subway No.1) to Yakusa (Aichi Ring railway): 9.2 km, 9 stations, double track.
Demand Capacity; 30,000 passengers/day (3,500 passengers/hr/each direction)
Route Profile; The route profile of TKL line is shown in Fig.-1. Toujishiryoukan-minami station which is located near the TKL train depot is the highest point of this TKL line. Toward that highest station there exists maximum gradient 6% slope. Because of such steeper slope is one of the reasons by which HSST system was selected as the transportation means of this TKL line.

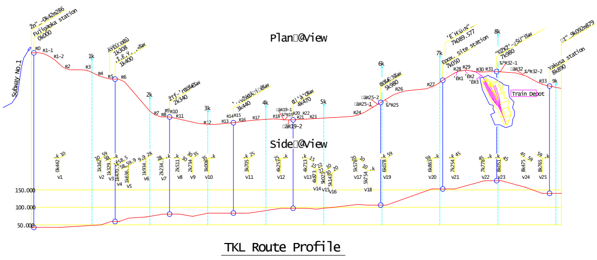

Fig.-1 Route Profile of TKL Line

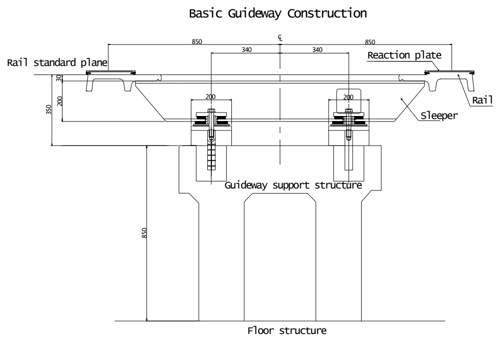

Fig. 2 Typical Guide-way Cross-Section

The system elevated guideway and piers were constructed as part of the public roads using the infrastructure support budget. Other non-infrastructure items, including the vehicle and the other electrical systems and facilities, were constructed, tested and operated by a joint venture, Aichi Kosoku Kotsu (AKK) Co., which consists of the Aichi Prefecture, neighboring local governments and private business companies such as Nagoya Railroad Co..

3.1 System Layout

3.1.1 Route

From Fujigaoka (Eastern terminal of Nagoya
Subway No.1) to Yakusa (Aichi Ring railway):
9.2 km, 9 stations, double track.

3.1.2 Demand Capacity

30,000 passengers/day (3,500 passengers/hr/each direction)

3.1.3 Infrastructure

Mainly it's constructed as elevated guideway above an existing public road. Approximately 1.3 km between Fujigaoka and Hanamizuki (except for the station area) and Fujigaoka station is located underground. Other stations are either on the ground or elevated.
The maximum gradient is 6% for a distance of 1 km leading to the top of the Eastern Hillside.
The minimum radius of horizontal curvature is 75 m for the main line track and for the side track. The short radius curvature is located at the road intersections while the other sections have approximately 400 m radii.
The min. vertical curve radius is 1500m and max. superelevation angle is about 6 degrees.

3.1.4 System Description

Normal Conductive Magnetic Levitation System (HSST-100 Type).
Unmanned operation by ATO control system.
The fleet consists of eight three-car trains. (Additionally one train is added during Epox. Opening period.)
Electricity: 1500V DC supplied by rigid trolley lines at both sides of the girder.
The system is fed from one substation located near the center of the line under the elevated guideway.

3.1.5 Guideways

The standard guideway construction is shown below as for the structure to install the rails for levitation and lateral guidance connected to the running road support guideway basement with the sleepers and the aluminum reaction plate is installed on the upper surface of the rail.

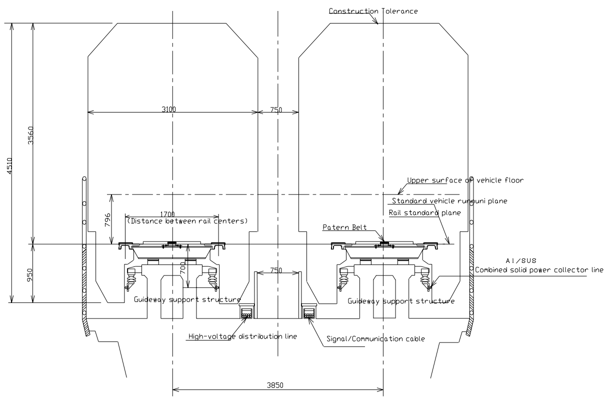

Fig. 3 Basic Guide-way Construction

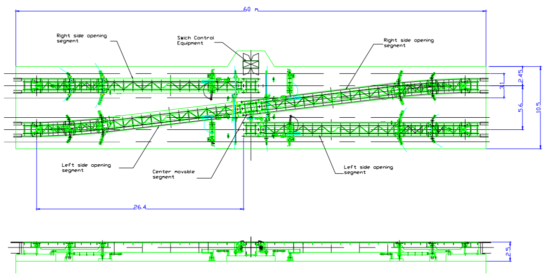

Fig. 4 Scissors-type Switch

3.1.6 Track Switch Characteristics

There are two types of switches in use on the Tobu Kyuryo Line: the segmented two-way/three-way switch and the crossover/Scissors type switch.
The segmented switch is of the same basic design as the switch that has been in place at Oe test track for the past ten years and has proven its reliability during more than 100,000 cycles of operation. This switch consists of three straight segments of unequal lengths that are swung into place by electric actuators. This segmented track allows the beam to go from a straight position to a curved one and is the most commonly used type of monorail switch in Japan.
Its schematic plan view is shown in Photo-2. Its cyclic operational time is 15 seconds.

Photo-2 The Segmented type switch

The other type of switch, located at the two terminal stations of the Tobu Kyuryo Line, is the crossover/ scissor type switch, developed as a variation of the single segmented switch that allows a vehicle to transition from one side of a dual guideway to another for crossover moves. This new switch type, which moves to the smooth track curvature, includes the trolley line and signal loop line. The switch consists of 2 right-side opening segments, 2 left-side opening segments and 1 center movable segment (Refer to Fig. 4). The switching time is 15 seconds, maximum. (Total cyclic time is 36 seconds.)

3.1.7 Maintenance Depot

Photo-3 Picture of Train Depot

In the east side of the main Expo. Site (the former Aichi Youth Park) is the location of the control center for operation and electric power supply, train depot, maintenance yard and the main offices.
This total area is about 38,600 square meters.

3.2 Schedule

The construction of the vehicle and the guideway began in April 2002. The prototype 3-car train was manufactured in October 2002 and was conducted performance verification tests at Oe test track. The train depot construction was completed in last September, and all project construction including underground tunnel section 1.3 km will be expected to be completed at least 4 months before the Exposition opening in March 2005 for the necessary verification and confirmation tests.

4. HSST Vehicle Performance Characteristics & Specification

Photo-4 Tobu Kyuryo Line- 3-car Train & Depot Photo-4 shows a 3-car train for Tobu Kyuryo Line.

4.1 Technical data

4.1.1 Train Unit
Fixed 3-car train (Mc1+M+Mc2)

4.1.2 Vehicle Dimension
The total Train Length is 43.3m (Including end couplers)
End Car (Mc Car) Length is 14.0m Middle Car (M Car) Length is 13.5m
Vehicle Width is 2.6m Vehicle Height 3.445m (above rail reference plane)

4.1.3 Maximum Design Empty Wt.
17.3 ton/car

4.1.4 Seating Capacity

	Mc Car	M Car	Total Capacity
Seated	34	36	104
Standing*	46	48	140
Total/train*	80	84	244

*Nominal Capacity: 0.3 m^2/ standee

4.1.5 Vehicle Performance Data
Max. Operating Speed 100 km/h
Acceleration Max. 4.0km/h/sec. (with passenger load compensation)
Deceleration
Full service braking 4.0km/h/sec. (with passenger load compensation)
Emergency braking 4.5km/h/sec. (with passenger load compensation)
Back-up braking 3.0km/h/sec. (Max. Wt.)

4.1.6 Summary of Principal Specification
Car Body Structure is of semi-monocoque construction, consisting of welded aluminum alloy structure with two emergency end doors, 2 entrance doors/side/car (1200mm width, 2 directional opening), seats in semi-cross seating, air suspension system and flexible multi-module, 5 coupled-modules/car.

Body structure	Made of welded aluminum alloy Head part with emergency door Two side doors per side (double door type with 1200mm opening width)
Carbody suspension system	Flexible pair module type: 5ea / car Air spring as the secondary suspension
Levitation and guidance device	U-shape normal conductive magnets and combined levitation and guidance type
Propulsion unit Main electric motor Control device	Linear induction motor (ten/car) IGBT VVVF inverter control (one/car)
Braking device Normal brake Emergency brake	Primary electrical brake (regenerating and reverse phase) by LIM with load compensator Pinching-type hydraulic brake with Stand-by brake system Hydraulic Brake 6ea / car
Auxiliary power unit	High freq.: DC-DC converter (two/3-car train) Output DC275V、DC100V and AC100V Battery 20Ah×2pair / train
Signal protection device	On-board signaling system, ATC, Continuous position detection by chek-in & check-out method
Operation device	ATO system
Train radio	Inductive radio（including emergency reporting function）
Operation control	Operation control by TIMS as primary device
Other devices	Air-con equipment 2ea / car, Heating devices under seats, Emergency evacuation device etc.

Table-1 Basic System Specification Table

The levitation and guidance system (LGS) provides vehicles with non-contact support of the vehicle with high reliability and high stability. (Refer to Fig.5.)
LGS functions independently on each module and is supplied from 275V DC bus and controlled by each Magnet Driver Unit (MDU). Magnets are of normal conductive and attractive type. The levitation control system consists of a MDU and sensors and provides a contactless stable support of the vehicle.
The Propulsion system consists of one VVVF (Variable Voltage Variable Frequency) inverter, which transforms DC power into an appropriate AC power for the linear induction motor (LIM), with ten LIMs for every car. The propulsion force is generated by LIMs when the VVVF inverter supplies the AC power. The electrical braking force is also generated by LIMs under the control of the brake command controller.

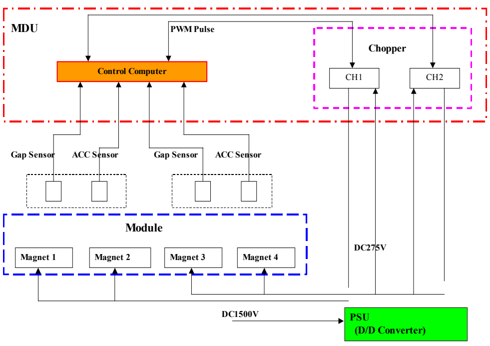

Fig. 5 Levitation and Guidance system

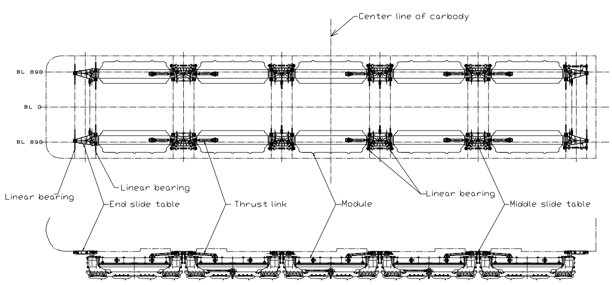

Fig. 6 Longitudinal body

Main Motor: One-side LIM 10ea/car
LIM Specifications:
・Thrust(nominal): 3000 N/LIM
・Phases/Poles: 3 phases/8 poles
・Material of Coil: Aluminum
・Current (Max.): 380 A
・Secondary Conductor (track): 4 mmt Al. plate
Control equipments: VVVF Inverter 1ea/car

Major Specifications of VVVF Inverter:
・Trolley Rail Voltage: 1500 V DC
・Max. Output Voltage: 1100 V AC
・Max. Capacity: 1487 kVA/1 unit
・Frequency Range: 0-90 Hz
・Type of Control: Voltage control type, Pulse Width Modulation (PWM)
・Cooling Type: Forced air-cooling

Suspension System

While the primary suspension of the vehicle is provided by the levitation and guidance system, the secondary is provided by air springs and lateral mechanical linkages.

・Air Suspension System: An individual module is supported with the air springs of two diaphragm types installed forward and afterward of each module and two sliding tables on the body sides.
As for the weight of the body, its load is transmitted to the modules through the air springs and oppositely force to work the module is transferred to the body with damping through the air spring and has improved riding comfort of the vehicle.

・Lateral Mechanical Suspension System:
A mechanical lateral system consists of the sliding stand (slide table), the horizontal guide link, the cable arm, and the link cable, etc. and has the function to distribute equally a horizontal lateral load of the body derived from the centrifugal force in running along the curvature and received in the crosswind and to transmit to each module, and in the curve section to move each module to the best position along the curve mechanically.

・Longitudinal Mechanical Suspension: It consists of linear bearings installed on the lower surface of the vehicle body floor, slide tables and thrust rods connected to slide tables. It conveys linear motor thrust and brake force. (Refer to Fig. 6)

Braking System

The basic brake mechanism of the Linimo vehicle adopts not the air brake method used with other conventional railway vehicles but the hydraulic oil pressure brake method so that its brake system may be required weight saving and space-saving.

And moreover, the use of the friction brake is eliminated as much as possible as well as the method which stops only with the electric brake developed with the current railway vehicle recently, and it's aimed at reducing maintenance and saving resources and environmental correspondence and almost of the brake power used regularly is obtained with the electric brake.

Service Braking: Primary electrical braking, electrical & hydraulic co-operated braking with passenger load compensation

Emergency Braking: Hydraulic braking by pressing on the rail surfaces

No. of hydraulic Brakes: 6 units/car

Hydraulic Brake System: Each car has an independent hydraulic system. The hydraulic brake system consists of the section of hydraulic power brake pressure control and brake actuators.

This system operates at pressure of 21 kgf/cm^2 (3000psi) and uses synthetic fire-resistant fluid (Quinto lubric 822 series) as the hydraulic fluid.

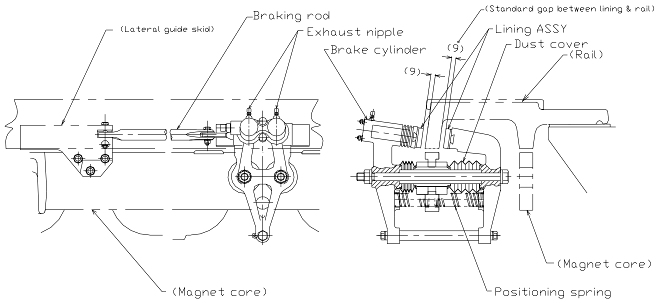

Fig. 7 Hydraulic caliper-type brake device

The principal component of hydraulic power section consists of the hydraulic pump, the primary and the stand-by accumulator, and the pressure switch. The brake pressure control section has three subsystems;

・Service Brake pressure control
・Emergency brake pressure control
・Stand-by brake pressure control

For hydraulic brake device refer to Fig. 7.

Modules: The HSST-100L vehicles are equipped with ten modules under-car (five on each side of the car), which provide the levitation and propulsion. Each module consists of gap sensors, landing skids, emergency rollers, linear induction motors, levitation magnets and hydraulic brakes.

Emergency Roller System: It is a device which supports a vehicle concerned on the rail upper surface (skid side) by extending the emergency rollers in one car respectively by an instruction from the ground after information on the breakdown etc. is sent to the operation control center through the data transmission by the operation from the driver's console or the inducement wireless.

In this case, because the lateral guidance force as levitating is active cannot be gained when running by the emergency roller device, the vehicle will be led with two lateral guidance skids installed in each module.

Electrical Power System: The electrical power system of the vehicle consists of an on-board power converter/inverter equipments (refer to as the power supply unit), input switch and battery. The power supply unit (PSU) transforms the high voltage direct current (1500 V DC) picked up by current collectors unit into the following 3 types of electrical power:

Photo-5 Control Console Panel

・Main 275V DC Power for levitation and A/C
・100V AC 60Hz Power for general use
・100V DC Power for control & communication

The PSU consists of high voltage inverter section (H-INV) box and low voltage converter section (L-INV) box.

Vehicle Control System: This system consists of the following three interconnected subsystems:

・Control Console
・Train Integrated Management System (TIMS)
・Visual Display Terminal (VDT)

The control console, installed at the front of each end-car, consists of control panel, display panel and the supplemental panels.(Refer to Photo-5.)

The TIMS is always monitoring control information of the driver's console and each equipment, displays to the drive control of the train and the driver's console, conducts each check and the inspection additionally, makes the instruction staff's (drive member) working load reduced, supplies an adequate information to the instruction staffs and enables the maintenance staff's reduction. And moreover, the control function of each equipment is controlled in an integrated manner by using the software logic and the serial transmission function, the uselessness of the number of parts and wiring is reduced by doing it while improving its function, and it can be optimized as a vehicle system.

This system has also the following functions such as data collection and processing, management of vehicle subsystem and maintenance support:

・Data collection and processing
  TIMS control unit collects the vehicle condition signals from subsystems and processes the data for management.

・Management of vehicle subsystem such as auto braking, acceleration inhibition, levitation inhibition and vehicle control panel indicator

・Maintenance support
  TIMS automatically conducts checks including pre-departure checks. TIMS is also collecting the data of major components for the regular inspections and maintenance work.

Visual Display Terminal (VDT):

The function of this equipment is to acquire data, diagnose data and display the results. This equipment receives the vehicle condition data from TIMS control unit and displays it on the display panel of the control console.

Photo-6 Train Operation Control Center
(Refer to Photo-5.)

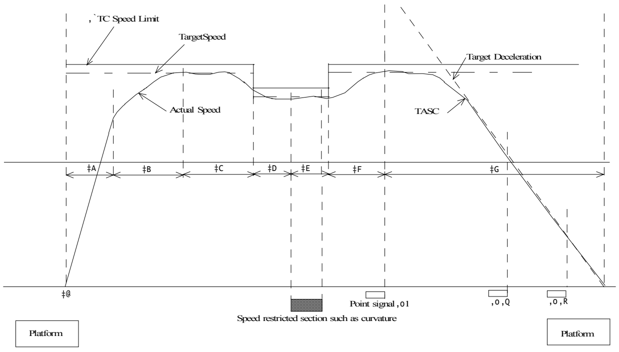

Fig. 8 Typical Running Profile by ATO

The following additional operational data is also displayed:

・Levitation condition
・Door open/close condition
・States of various systems
・Present time

A memory card is installed for off-line fault data diagnosis.

Automatic Train Control System (ATC)

To ensure safety of train operation, the train protection system consists of signaling equipment units including Train Detection System (TD), on-board ATO equipment for automatic train control, and Automatic Train Protection (ATP) equipments.

On-board ATO equipment controls stopping and starting of trains, door opening sequence and train departure control at each station, utilizing ATO Data Communication System and transponder at stations.

When the vehicle is between stations, the on-board ATO system performs train speed monitoring and control, based on ATP speed limit aspect received from the wayside pattern belts on the guideway. When approaching a station, a transition to TASC control occurs and the train stops at the programmed position at each station, based on the programmed stopping pattern triggered by the positioning transponder. Refer to Fig.- 8.

5. Concluding Remarks

Almost a quarter century has passed since the first HSST Maglev system development began in Japan and finally the Aichi Eastern Hillside (TKL) Project has begun and almost completed at present through the great efforts, cooperation and advice of many concerned people including Aichi-prefecture local government.
In the near future we desire to make the HSST system a universal mode of urban magnetic levitation vehicle system as the newer transportation means in the 21-th century.

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