High Speed Surface Transport System: Nagoya East Hillside Line and the Operational Testing for 3-Car Vehicle Prototype

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Abstract

The East Hillside Line in Nagoya (also referred to as Tobu Kyuryo Line) is the world's first commercial application of the magnetic levitation system for HSST that is now starting its construction for the grand opening of the World Exposition, "Aichi Expo 2005" scheduled for March 2005.

This report summarizes the development history of the HSST system and its latest status including design concept of prototype vehicles for Tobu Kyuryo Line.

1. Introduction

The High Speed Surface Transport (HSST) is a normal conductive system levitated by the attractive power of magnets and propelled by a Linear Induction Motor (LIM) without wheels - completely different from conventional railways. Because there is no contact of running equipment, this system has virtually no noise, vibration, and almost no frictional wear compared with the conventional railroad systems. This system is very suitable as a new urban transport system for the new century because it is environmentally friendly, economical, and low maintenance cost characteristics.

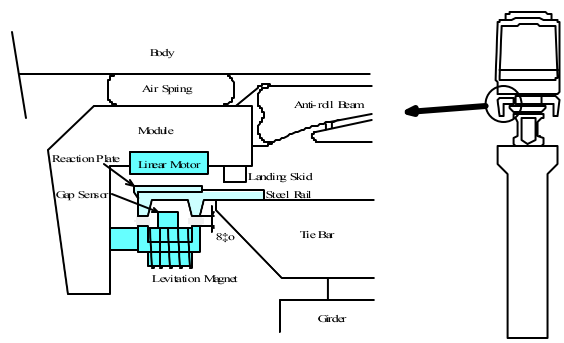


Fig.-1 Cross section of HSST-100 system

2. Development Process of HSST

Starting in 1972, the Japan Airlines Company began to develop faster and more convenient airport access lines from Narita Airport to downtown Tokyo, Sapporo to Chitose Airport, or other similar lines potentially using HSST. In 1985, the HSST-03 type vehicle was successfully tested and operated during the World Science Exposition at Tsukuba City (located in the northern part of Tokyo) and was highlighted as a viable urban transport system. After that event in 1989, the Chubu HSST Development Company, sponsored by the Nagoya Railroad Group, Aichi Prefecture and the HSST Company, was established to further develop commercial practical use of HSST. Thereafter, the Aichi Prefecture local government established a Feasibility Study Committee to oversee this technology.

In 1991, the Oe Test Line was constructed in the southern part of the city of Nagoya for running tests operation by HSST-100 and continued successfully for two years. As a result of running many tests, the Japanese Authority concluded that the HSST system had no technical problems and approved its future commercial use as an urban transport system by confirming its very satisfactory safety and reliability characteristics. In 1995, a new "stretched" model HSST-100L vehicle was introduced on to the test line and additional testing was performed for further confirmation, durability, improvement and development.

Concurrently, the Aichi local government chose the HSST system as a new usable technology for implementation in the Aichi Academic Research and Development zone in East Hillside area near Nagoya. In February 2000, a quasi-public corporation named Aichi Kosoku Kotsu Co. was established for construction of non-infrastructure components with its goal to insure the opening of this new line in March 2005.

Photo-1
HSST-100L(right)and 100S vehicles(left)

3. The World's First Commercial HSST Line - Tobu Kyuryo Line

The Tobu Kyuryo Line will be a middle-capacity connector line that will serve as a means of connecting the Fujigaoka station, located at the terminal of the Nagoya subway line (Higashiyama-Line), to the Yakusa station of the Aichi Ring railway, a distance of approximately 9 km. The line is expected to provide a convenient means of monitoring all aspects of the system (e.g., ridership, power consumption, reliability, etc.) for the Aichi Academic Research and Development zone. Refer to Figure 2.

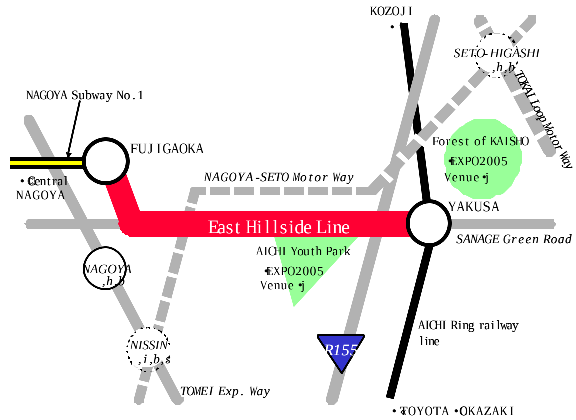


Fig.-2 Route Map of East Hillside Line

The total estimated construction cost of the Tobu Kyuryo Line is 100,000 million yen (US$770 million). The system guide way and elevated piers will be constructed as part of the public roads using the infrastructure support budget. Other non-infrastructure items, including the vehicle and the other electric facilities, will be constructed, tested and operated by a joint venture, Aichi Kosoku Kotsu Co. which consists of the Aichi Prefecture, neighboring local governments, and private business companies.

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 Demanded Capacity

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

3.1.3 Infrastructure

.Mainly constructed as the elevated guide-way above an existing public road.

Approximately 1.3 km between Fujigaoka and Hanamizuki (except for the station area) is a tunnel to be constructed by a shield construction method. Refer to Figure3.

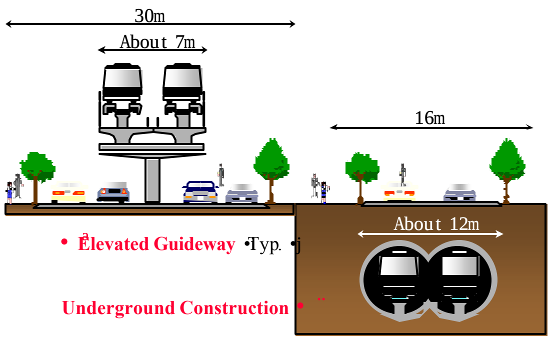


Fig.-3 HSST Guide-way Structure

.The Fujigaoka station will be located under ground. Other stations are to be located either at-grade or elevated.

.The maximum gradient is 6% for a distance of 1 km up to the top of the Eastern Hillside.

.The minimum radius of curvature is 75 m. This short radius curvature is located at the road intersections while the other sections have approximately 400 m radii.

3.1.4 System Description

. Normal Conductive Magnetic Levitation System (HSST-100 Type)

.Assume un-manned operation by ATO control system

. Fleet consists of eight three-car trains (Additional a few car trains will be used during the World Expo.)

. Electricity: DC1500V supplied by rigid trolley lines at both sides of the girder. One substation is located at the near center of the line under the elevated girder.

3.1.5 Track Switch Characteristics

At the two terminal stations of the Tobu Kyuryo Line, 3-way scissor type switches are provided for crossovers.

This new switch type is derived from an existing 2-way switch that transfers rail and girder simultaneously and has a proven performance, reliability and durability.

The three-way switch consists of three segmental rails and girders and moves to the smooth approximate curvature including trolley line and signal loop line. And it also consists of 2 right-side opening segment, 2 left-side opening segment and 1 center movable segment (Refer to Figure 4). The switching time is 35 seconds, maximum.

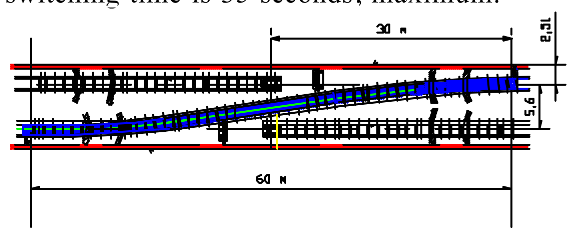


Fig.-4 Scissors-type Switch

3.1.6 Train Depot

In the east side of Aichi Youth Park will be located 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. Refer to Figure 5.

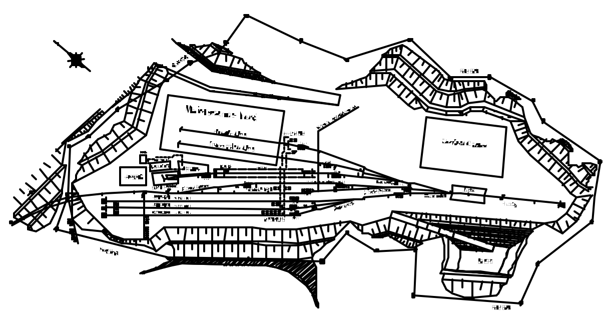


Fig.-5 Plan View of Train Depot

3.2 Schedule

The construction of the vehicle and the guide way will have started by April 2002.

4. Vehicle Specification for the Tobu Kyuryo Line

Figure 6 shows a 3-car train for Tobu Kyuryo Line.

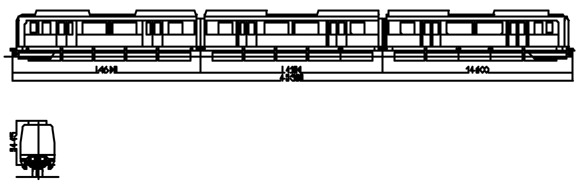


Fig.-6 Imaginary View of Tobu Kyuryo Line 3-car Train

4.1 Technical data

4.1.1 Train Unit

Fixed 3-car train (Mc1+M+Mc2)

4.1.2 Vehicle Dimension

Total Train Length	43.3m (Including end couplers)
End Car (Mc Car) Length	14.0m
Middle Car (M Car) Length	13.5m
Vehicle Width	2.6m
Vehicle Height	3.445m (Height from 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*	47	46	140
Total/train*	81	82	244

*Nominal Capacity: 0.3 ..465 sq. in. ..standee

4.1.5 Vehicle Performance Data for acceleration and deceleration

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	Welded aluminum structure with emergency end Doors: 2 entrance doors/side/car (1200mm width, 2 directional opening) Seat: Semi-Cross seating
Suspension System	Flexible multi-module, 5 coupled-modules/car
Levitation And Guidance	Normal Conductive with attractive magnetic force for levitation and lateral guidance
Propulsion	Main Motor: One-side Linear Induction Motor 10ea/car Control equipments: VVVF Inverter 1ea/car
Braking Device	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 hyd. Brakes: 6 units/car
Aux. Power Unit	High Freq. DC/DC converter Output: DC275V, DC100V and AC100V Battery: 20 Ahx.units/Train
ATC(Automatic Train Control)	Automatic Train Protection (ATP) with CAB-signal output Continuous position detection system with check-in & check-out signals
	Automatic Train Operation.ATO.including Automatic Speed Regulation and Automatic Station Stopping
Voice Communication System	Inductive Radio including Emergency Alert
Other Equipment	Cooling device: 2 ea/car, Space for handicapped personals at backside of the driver's seat and evacuation equipments etc.

4.2 Comparison of Tobu Kyuryo Vehicle with the basic HSST-100L vehicle

4.2.1 Main Differences

	Basic HSST-100L	Vehicle for Tobu Kyuryo Line
Train Unit	2-Car train (Mc1+Mc2)	3-Car train (Mc1+M+Mc2)
Max. Acceleration	4.5 km/h/s	4.0 km/h/s
Inverter element for control equipment	Mc1: IGBT Mc2: GTO	IGBT
Hydraulic Power Source	1 unit for train	Independent unit for each car (Total 3 units/train)
Operational Control Systems	SVS (Supplemental Vehicle Control Sys.) MVS (Main Vehicle Control Sys.) MSU (MSU Sub Unit) VDT (Visual Display Terminal)	TIMS (Train Integrated Management Sys.)
ATC (Automatic Train Control)	ATP (Over-run protection only)	ATP (Automatic Train Protection Sys.) ATO (Automatic Train Operation Sys.)

4.2.2 Purpose of TIMS Introduction

The Train Integrated Management System (TIMS) is an on-board piece of equipment, which collects and integrates the information of the train operation and the operating condition of each vehicle subsystem. TIMS continuously processes data to ensure proper system function and collects information on major system components for malfunction and maintenance support.

The purposes of TIMS are as follows.

.Operation and Maintenance Support

Arrangement of many kinds of signals and simplification of the driver's workload; also, maintenance work equipped with maintenance support functions including automation of the departure or arrival inspection in the maintenance depot.

.Reduction of Connecting Lines between Cars

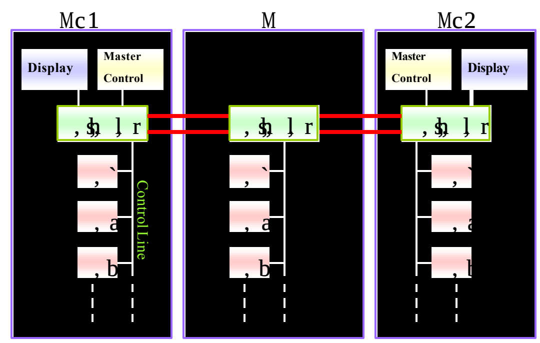
Reduce connecting lines between cars and also between equipments in each car using communication by highly reliable serial transmission. Refer to Figure 7.

.Changes the switchboard function to software

to reduce the number of components by changing relay logical circuits which are used in switching and distribution board to software.

.Transition to a General-Purpose System

To improve maintenance efficiency by changing the existing HSST-100L specific operation control systems including SVS, MVS, MSU and VDT to the general-purpose TIMS for Tobu Kyuryo Line.



Concentrate all information into two transmission lines

Fig.-7 TIMS Schematic

4.2.3 Automatic Train Control System (ATC)

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

On-board ATO equipment has the function of automatic control of stopping and starting of trains, door opening sequence and train departure control at each station by cooperation with ATO Data Communication System and transponder at stations.

When the vehicle is between stations, the on-board ATO system conducts train speed control monitoring based on the ATP speed limit aspect received from the pattern belts, which are installed on the guide-way.

When approaching the next station, a transition to TASC control train occurs and the vehicle is stopped at the programmed position of each station based on the programmed stopping pattern triggered by the positioning transponder. Refer to Figure 8.

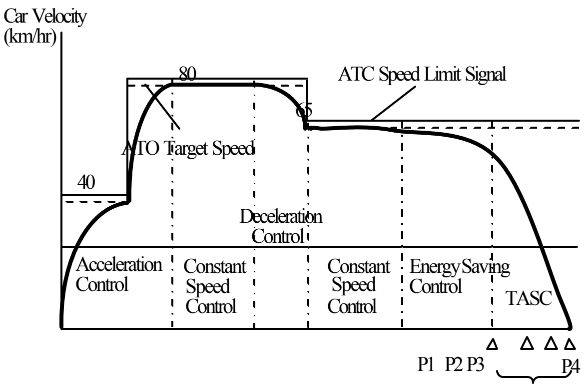


Fig.-8 Run-Curve Simulation

4.3 Confirming Tests Schedule of Prototype 3-Car Vehicle

Several confirmation-running tests at the Oe Test Track are planned using one prototype 3-car vehicle before the completion of the Tobu-Kyuryo Line construction. The new HSST vehicle has specifications for the equipment that are different from the existing 2-car test vehicle. However, some partial modifications including module and power collecting equipment and temporary installation of ATS on-board equipments will be necessary for completion of the running test of prototype vehicle at Oe Test track because of different guide-way specifications between the Oe Test Track and main Tobu Kyuryo Line.

5. Other activities for Potential Overseas HSST Projects

5.1 Joint tests with Kowloon-Canton Railway Corporation (KCRC)

KCRC had a concern of whether the HSST was feasible to be adopted for an urban mass transit application in Hong Kong.

In order to confirm any indication, a series of test trials were conducted in December 2000 jointly by KCRC and CHSST.

Refer to the contribution of "Failure Mode and Endurance Tests of the HSST 100L System" by Dr. L. K. Siu, KCRC in detail.

5.2 FTA(Federal Transit Administration) Urban Maglev Development Program

The proposal which had been submitted to FTA by the Maglev Urban System Associates (MUSA), a consortium of Earth Tech., Chubu HSST, Kimley-Horn & Associates, Chamberlain Engineering and Delon Hampton & Associates, was awarded in September 2001. The MUSA team is now aggressively conducting an in depth study for the adaptability of the Chubu HSST System for use in the United States.

6. Concluding Remarks

Almost a quarter century has passed since the first HSST development started in Japan but finally the Aichi Eastern Hillside Project has begun through the great efforts, cooperation and advice of many concerned people.

In the future we desire to make the HSST system a universal mode of urban magnetic levitation transportation.

English version is here.

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