

Summary of automatic operation of Linimo and achievement in opening year

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ABSTRACT: Tobu-Kyuryo-Line is a mid size transport system which adopts HSST system and automatic operation. In HSST system vehicle is levitated with normal conducting electro-magnet and is propelled with Linear Induction Motor. Low noise by levitation and stable acceleration by LIM is starting point for improvement of riding comfort and faster transport. Automatic operation is indispensable for stable operation and reduction of running cost. In the opening year Tobu-Kyuro-Line played very important role as an access transport for EXPO2005 carrying 20 million. So far it does not have serious trouble and is operated safely. In this paper, we describe automatic operation of Tobu-Kyuryo-Line and operating results such as number of passengers, power consumption and consumption of pads in opening year.

1 INTRODUCTION

Tobu-Kyuryo-Line connects Fujigaoka station which is a terminal of Nagoya city subway and Yakusa station of Aichi Loop Line.

More than 20,000 application were subscribed for nickname of this line. "Linimo" was selected as the nickname because it is familiar and easy to remember and it makes us imagine linear motor car.

Infrastructure such as piers and girders was constructed by Aichi prefecture and Nagoya city. Other part was constructed by Aichi Rapid Transit Co., which was founded as the third sector company in February 2000. The section from Fujigaoka station to Hanmizuki-dori station is underground and the rest is elevated.

Demand is estimated as 30,000 passengers a day and capacity during peak hour is 4000 passengers.

Figure 1 shows shape of this line. It is planned along roads and has as small as 75 m radius curve and as steep as 6 % slopes.

The system selection committee selected HSST system because it negotiates tight curve or steep slope and makes us feel sense of advancement.

Recently it is common for new transport system to reduce running cost by adopting automatic operation and this line also adopts automatic operation.



Figure 1: Shape of Tobu-Kyuryo-Line

2 EQUIPMENTS OF VEHICLE

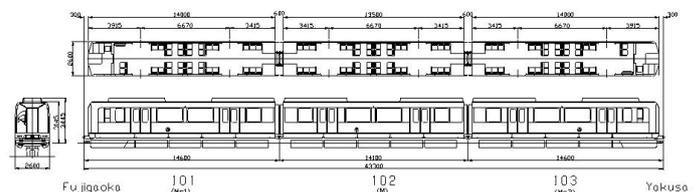


Figure 2: Outline of the vehicle

Figure 2 shows outline of the vehicle and Table 1 shows specification of the vehicle.

Table 1: Specification of the vehicle

Item	Content
Train	3 cars, 43.3 m
Size lead car	Length 14.0 m, width 2.6 m, height 3.45 m
middle car	Length 14.0 m, width 2.6 m, height 3.45 m
Capacity	244 passengers a train (incl. 104 seated) Lead car 80(34), middle car 84(36)
Body structure	Made of welded aluminum alloy Head part with emergency door Two double door type side doors per side with 1200mm opening width
Body suspension	10 flexible pair modules a car Air spring as secondary suspension
Levitation & guidance	U-shape normal conductive magnets & combined levitation and guidance
Propulsion	
Main motor	Linear induction motor (10 a car)
Control device	IGBT VVVF inverter control (1 a car)
Brake	
Normal	Electrical brake & hydraulic brake
Emergency	Hydraulic brake
Main power	DC1500V
Auxiliary power	DC-DC converter (2 a train)
Operation	ATO system
Performance	Maximum speed 100 km/h Maximum acceleration 4.0 km/h/s Maximum deceleration 4.5 km/h/s Maximum gradient 7 % Minimum curve radius 50 m

3 AUTOMATIC OPERATION

Automatic operation is already adopted on other transport system. Automatic operation of Tobu-Kyuryo-Line is designed on the basis of other transport system.

Main functions of automatic operation are start control, speed control, stop control and lower speed priority. 7 equipments are necessary for this system to work properly.

1. Automatic Train Operation equipment (ATO)
2. Train Integrated Management System (TIMS)
3. VELOCITY detection system equipment (VEL)
4. Inductive Radio equipment(IR)
5. Station control equipment
6. Automatic Train Control (ATC)
7. Train Detection equipment (TD)

3.1 Automatic Train Operation equipment (ATO)

Automatic Train Operation equipment (ATO) is necessary for Automatic Operation. Standard running pattern is saved in this equipment. This equipment gives instruction of propulsion or brake detecting speed and position. This instruction consists 31 steps for both propulsion and brake and makes speed control precisely. It is sent to VVVF inverter and brake controller through TIMS.

Running pattern was arranged once during EXPO2005. Former pattern took full advantage of vehicle performance. This pattern made running time shorter and gave longer staying time at stations. However acceleration and deceleration occurred by turns frequently and that made vehicle uncomfortable to ride in. This arrangement has made vehicle more comfortable.

Figure 3 shows basic running pattern. ATO always transmits and receive messages with other equipments.

3.1.1 Start control

ATO receives “start instruction” from station controller or “restart instruction” from operation room through IR. TIMS receives same instruction and levitates vehicle when it is ready. ATO check the information of TIMS and gives instruction of propulsion or brake to TIMS. TIMS orders release of brake and propulsion to relevant equipments.

3.1.2 Speed control

Vehicle runs in accordance with running pattern saved in ATO. Target speed of ATO is 3 km/h lower than limit speed of ATC, which is designed on every signal block. Running pattern is designed so as not to exceed limit speed of ATC.

3.1.3 Train Automatic Stop Control (TASC)

ATO detects distance to target position so that vehicle stops at correct position of the station. Position informations of unpowered wayside coils, P1, P2 and P3, are transferred to ATO through station controller. Vehicle remembers stopping pattern when it receives information of P1 and runs in accordance with this pattern.

3.1.4 Lower speed priority

Lowest speed among speed of running pattern, limit speed of ATC, temporary speed sent from operation room and temporary speed regulated depending on condition of vehicle is the target speed of ATO.

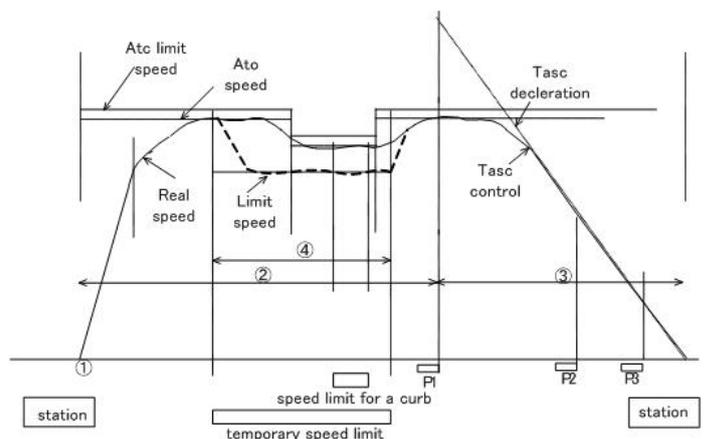


Figure 3: Outline of running pattern

Table 5: Achievement in opening year 2

A	B	C	D	E
3	1,194,464	82,414	3	133
4	2,422,625	81,524	10	100
5	3,009,994	84,479	2	108
6	3,165,392	81,239	6	126
7	3,147,397	84,461	12	178
8	3,589,211	84,052	12	77
9	3,902,172	78,676	13	88
10	326,742	59,132	9	110
11	300,961	57,316	3	52
12	239,514	58,989	1	79
1	249,407	58,989	0	58
2	216,891	53,685	1	86
3	234,615	59,416	0	119
Sum		924372		
Previously estimated value per year			917	1849
Actual value / Estimated value (%)	7.9		71.1	

- A. Month
- B. The number of passengers
- C. Running distance (km)
- D. The number of exchanged brake pad
- E. The number of power collecting pad

4.1 The number of passengers

Estimated number of passengers of Tobu-Kyuryo-Line is 30,000 a day. The number of passengers was 3.5 times estimated one during EXPO2005, but one third of estimated one after EXPO was over. However we expect that the number will increase as the area is being developed.

4.2 Power consumption

Average power consumption is shown as power consumption for a car to run for one kilometer. Previously estimated value is 4.046, but measured one in September was 44 % more than estimated one because of extremely high carrying weight and full working of air conditioner. In October or November, measured value came close to estimated one, but it had grown higher since December because of heater working.

4.3 Consumption of brake pad

The number of exchanged brake pad is estimated using the result of running test of HSST-100L. 72 pads, only 8 % of estimated number, were exchanged. One of the reasons is that vehicle speed at which brake is switched from electric to hydraulic, changed to 3 km/h from 10 km/h. Another reason is that hydraulic brake usually generates smaller brake force when operated automatically than manually because automatic operation has 7 steps for brake control which generate smaller brake force than the lowest step of manual operation.

4.4 Consumption of power collecting pad

The number of exchanged power collecting pad is estimated using the result of running test of HSST-100L. 1314 pads, about 71 % of estimated number, were exchanged. Material and shape of the pad are not changed from HSST-100L.

Pads are worn like they are grooved. We flatten them with grindstone. That leads smaller consumption of pads.

Figure 7 shows comparison between worn pad and flattened pad. Left is worn pad and right is flattened pad.



Figure 7: Comparison of power collecting pad

5 CONCLUSION

More than one year has passed since we start operation of Tobu-Kyuryo-Line on March 6. EXPO2005 was held soon after we started operation. Average number of passengers exceed 100,000 and total number was close to 20 million during EXPO. The number got larger and larger as the final day came closer and in September almost all trains were full of passengers from early morning to late at night. That situation was as hard as endurance test for first commercial application of HSST system. But we had accomplished very important role of access to EXPO site with technical skill obtained by HSST-100L or HSST-100S and support of manufacturer of this system.

We will make efforts to operate safely on time as important transportation system and to improve our service so as to increase the number of passengers.

Finally, we are grateful to Chubu HSST Development Co. which has played an important role since planning and thank all of companies which designed, manufactured and constructed Tobu-Kyuryo-Line.