Recent Progress of Urban Maglev Program in Korea

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ABSTRACT: This paper discusses the status of Korea's Urban Maglev Program which is the final stage of a series of R&D projects on the low-to-medium speed maglev transit system development. The goals of the program are to develop a competitive transit maglev system and to operate the developed system on the 6.1 km demonstration line on revenue service basis. Also the plan for the second urban maglev system application for Daejeon Metro Line #2 in the city of Daejeon, Korea is reported.

1 INTRODUCTION

In 2006, the Ministry of Land, Transport and Maritime Affairs initiated Urban Maglev Program to finalize the previous maglev R&D projects and to prove that the developed system is ready for revenue service. The Center for Urban Maglev Program was set up to lead the program. The objectives of the program are to develop the competitive urban transit maglev vehicle and to construct a 6.1 km urban maglev Demonstration Line at Incheon International Airport by August 2012. The maglev trains will start revenue service from 2013 after test and commissioning for 1 year, which is required by regulations. The total program budget is expected to be 375 million US Dollars, including contributions from the government, Metropolitan City of Incheon, Incheon International Airport and private sectors.

In the first stage of Urban Maglev Program, R&D activities to improve performance of maglev train are successfully completed. In December 2009, the prototype maglev vehicles were built and transferred to 1.3 km test track in KIMM, Daejon, Korea. Various tests are being performed until 2011. Also various guideway related technologies have been developed, including the articulated type turnout switches. In the second stage of Urban Maglev Program, the focus is shifted to the construction of Demonstration Line at Incheon International Airport and one year long test and commissioning.

2 KOREA'S MAGLEV DEVELOPMENT HISTORY

A R&D project for a low-to-medium speed maglev system started in 1989 by Korea Institute of Machinery and Materials (KIMM) with the financial support from the Ministry of Science and Technology. The development activities were centered at the maglev vehicle with electromagnetic suspension (EMS) and linear induction motor (LIM) propulsion. The first generation maglev trainset (UTM-01) with two vehicles was developed in 1998.

In 1997, 1.1 km long test track was constructed in KIMM, which was extended to 1.3 km in 2002. The test track has 4 and 6 % slopes and curve sections with radius of 60 and 180 meters. Figure 1 shows the 1.3 km test track in KIMM.

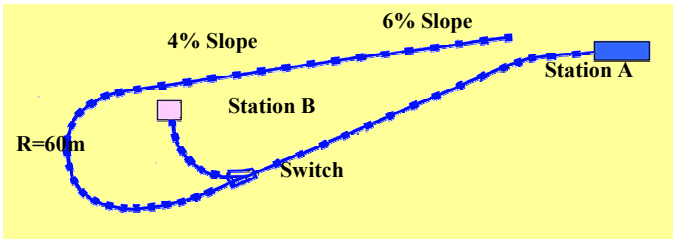

Figure 1. Test Track in KIMM (1.3 km)

The second generation maglev trainset UTM-02 was developed in 2005 by Hyundai-Rotem Co. with

the financial support from Ministry of Commerce, Industry and Energy. UTM-02 was developed to provide a shuttle service on the 1 km long single track between Expo Park and National Science Museum in Daejeon. The line was renewed by upgrading a section of existing Expo'93 Maglev track. Figure 2 shows UTM-02 trainset operating on Expo Park – National Science Museum line.

Figure 2. UTM-02 Trainset

3 URBAN MAGLEV PROGRAM

Urban Maglev Program is funded by Ministry of Land, Transport and Maritime Affairs (MLTM) with assistance from Ministry of Education, Science and Technology (MEST) and Ministry of Knowledge Economy (MKE) with matching funds from the participating private companies. The program is supervised by Korea Institute of Construction & Transportation Technology Evaluation and Planning (KICTEP).

The Program is composed of three Core Projects; Systems Engineering, Vehicle Development, and Demonstration Line Construction. The Core Projects are managed by KIMM, Hyundai-Rotem and Korea Rail Network Authority, respectively. The program schedule is shown in Table 1.

Table 1. Program Schedule

		07	08	09	10	11	12	13
R&D for Technical Improve-ments	Systems Engineering	———	———	———	———	———	———	———
	Vehicles (including performance test)	———	———	———	———	———		
	Guideway Facilities	———	———	———	———			
Demonst-ration Line Construc-tion	Site Selection	———						
	Line Design	———	———	———				
	Construction / Systems Integration				———	———	———	
	T & C*						———	———

*: Test & Commissioning

3.1 *Core Project 1: Systems Engineering*

The objective of Core Project 1 is to support management and integration of sub-systems for the successful implementation of Urban Maglev Program. Also, the interface management for system integration and the system management plan have been applied. Systems Engineering has five sub-projects; System Integration, Systems Engineering Process Definition and Requirement Management, Analysis of RAMS and LCC, Test and Evaluation, and Legislation/Amendment of Regulations.

The RAMS management plan are currently applied to vehicles as well as major subsystems such as signaling system, PSD(Platform Screen Door), communication system, and turnout switches.

3.2 *Core Project 2: Vehicle Development*

The objectives of Core Project 2 are to develop and commercialize three consists of driverless urban maglev vehicles of maximum speed of 110 km/h and to perform the comprehensive vehicle test. Vehicle Development has three sub-projects; Development and Production of Urban Maglev Vehicle, Performance Improvement of Levitation and Propulsion Systems, and Safety and Stability of Vehicle Considering Interaction with Guideway.

The sub-project 'Performance Improvement of Levitation and Propulsion Systems' upgraded the EMS levitation system and the propulsion system. The sub-project 'Safety and Stability of Vehicle Considering Interaction with Guideway' provided technical data to civil design of guideway by maglev vehicle/guideway dynamic interaction simulations based on virtual prototyping.

Figure 3 shows the developed maglev trainset which is composed of two married-pair vehicles. The frontal shape is designed to imitate the shape of Korea's traditional celadon porcelain. Also, the design is prepared to be compatible with Incheon International Airport, which has reputation of being one of the best airports in the world. The design specifications of the vehicle are listed in Table 2.

3.3 *Core Project 3: Demonstration Line Construction*

The objectives of this Core Project are to construct the 6.1 km Demonstration Line and to perform Test & Commissioning for safety verification and stabilization of vehicle operation.

Figure 3. Prototype Maglev Trainset on Test Track

Figure 4. Three Way Articulated Turnout

Table 2. Urban Maglev Train Specifications

Train Configuration	2 Cars, Permanently Coupled (Mc1+Mc2)
Vehicle Dimensions [m]	12.0 (L) x 2.7 (W) x 3.45 (H)
Vehicle Weight	Tare : 19 ton/car Laden : 26.5 ton/car
Passenger Capacity	115 persons/car [Standing: 5 persons/㎡]
Number of Bogies	4 per Car
Propulsion System	LIM + VVVF Inverter
Levitation System	ElectroMagnetic Suspension Type, 8 mm air gap
Brake System	Combination of Regenerative & Mechanical Brake
Power Supply	1,500 VDC
Max. Design Speed	110 km/h
Max. Operating Speed	80 - 100 km/h
Max. Acceleration	4.0 km/h/s
Max. Deceleration	4.0 km/h/s in Service, 4.5 km/h/s in Emergency
Ride Quality Index	below 2.0 of UIC
Max. Gradient	70 ‰
Min. Curve Radius	50 mR

For the commercial application of Urban Maglev, both the improvement of maglev guideway technology and the economical rapid construction technology in urban area are important. Also, the development of high speed articulated turnout switches having less than 25 second switching time are required.

Hence, Core Project 3 is composed of three sub-projects; Line Construction, Improvement of Maglev Guideway Structure, and Development of High Speed Articulated Maglev Turnout Switch. Figure 4 shows the developed three(3) way articulated turnout switch under long-term operation test. In addition to the 3 way, 2 way and X type turnout switches, composed of four 2 way turnout switches, will be installed in the Demonstration Line.

4 DEMONSTRATION LINE

The consortium of Incheon International Airport and Incheon city was selected to hold the 6.1 km maglev Demonstration Line as the first phase of total 3 phases (57km in total) in 2007. The Demonstration Line design is completed in Oct. 2010. The construction started since Feb. 2010 by the consortium led by GS Engineering & Construction. After the construction of 6.1 km double track, six stations and a maintenance depot in 2012, one year long test and commissioning will be performed in accordance of government regulations. From late August 2013, four consists (eight vehicles) will be in commercial operation on Demonstration Line.

Figure 5 shows the bird's-eye view of Demonstration Line. The pillar and guideway are designed to be slim, light, aesthetically appealing and cost competitive with those of other LRT systems.

Figure 5. bird's-eye view of Demonstration Line.

Figure 6 shows the designs of six stations. All stations will be aesthetically appealing to the very high standards of Incheon International Airport enhancing comfort and convenience of the passengers. Figure 7 shows photos of guideways under construction. The red and green-color protection fences in the photos are installed temporarily for the safety of workers, and will be removed later.

Figure 6. Station Designs

Figure 7. Guideways under Construction

5 PERFORMANCE TEST ON TEST TRACK

The performance test for the new maglev vehicles have been conducted on the test track since March 2010 including various type tests to confirm the vehicle performance. Also test articles specified in Urban Railway Act and Enforcement Decree of the Urban Railway Act of Korea have been applied.

Figure 8 shows one example of powering and braking performance tests of the maglev trainset. The figure shows the maglev vehicle's acceleration to reach top speed of about 53 km/h from standstill in about 12 seconds following the propulsion(notch) command. The acceleration and deceleration capabilities are confirmed to meet the requirement of 4.0 km/h/s. The prototype maglev vehicles also provide excellent ride quality performance. The noise level in the cabin is lower than 65dB(A) even when the air-conditioner is at full power. Table 3 shows the ride quality index of the vehicles.

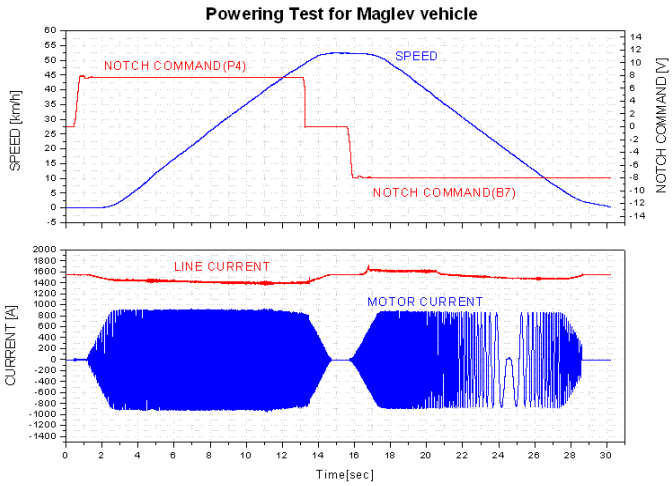

Figure 8. Example of Powering and Braking Performance Test

Table 3. Measured UIC Ride Quality Index

Vehicle	Average	Min.	Max.
MC 1	0.4438	0.3045	0.5493
MC 2	0.4194	0.3340	0.5324

6 PLAN FOR DAEJEON METRO LINE 2

Daejeon Metropolitan City ("Daejeon") is recently planning to apply the maglev train for Metro Line 2. Daejeon requested to the central government to perform the preliminary feasibility investigation, which was endorsed by the Ministry of Land, Transport and Maritime Affairs and forwarded to Ministry of Strategy and Finance. It is expected that the feasibility investigation is passed by June 2012, and the line design and installation process will start right away.

6.1 Overall Status of Daejeon Metropolitan City

Daejeon is located in the center of Korea, and its size and traffic volume as of 2011 are as follows:

- Size: 539.86km^2
- Population: 1,518,000 persons
- Density of Population: 2,811 persons/ km^2
- Number of registered cars: 578,033 units
- Subway with conventional steel wheel / rail system (Metro Line 1) is under operation (L=22.6 km)

6.2 Selection of Vehicle Type

Daejeon Metro Line 2 is required to efficiently deal with the increase of transportation demand pursuant to the change of urban transit conditions such as the increase of population, reorganization of urban area structure and magnification of various lifestyle zones due to the city development program of Daejeon. The requirements for vehicle type for Daejeon Metro Line 2 appropriate for the urban conditions of Daejeon are as follows:

- A highly rapid and punctual system considering the transit conditions of Daejeon
- A system that can increase the use of public transportation by providing quality public transportation service for citizens.
- A system which can secure the sustainable urban transit system through low carbon green growth
- A system which can minimize the environmental adverse effect (noise, vibration or aesthetic visual quality) around the route
- An economically feasible system in the respect of the construction and operational costs

Tram, steel wheel AGT, rubber tyre AGT, monorail and maglev systems were considered for selection, among the urban transit system currently in operation worldwide. The maglev system is determined to be suitable for the urban transportation requirements of Daejeon, and also environmentally excellent in respect of the noise, vibration and aesthetic visual quality.

6.3 Route Plan

For Daejeon Metro Line 2, the construction of 28.6 km of the line will be completed in the first stage in connection with urban developments, and an additional 7.4 km of the line will be completed in the second stage. The revenue service of the first stage is scheduled to commence in 2019. Table 4 shows the summary of Daejeon Metro Line 2. Figure 9 shows the line map, and figure 10 a graphic representation in downtown area

Table 4. Summary of Daejeon Metro Line 2

Length	36.0 km
Stations	30 stations
Distance between stations	1.19 km
Construction method	Overhead: 33 km Underground: 3 km
Number of passengers per day	128,074 persons/day
Number of passengers per day per km	3,598 persons/day/km
Estimated construction cost	KRW 1,717,100 million

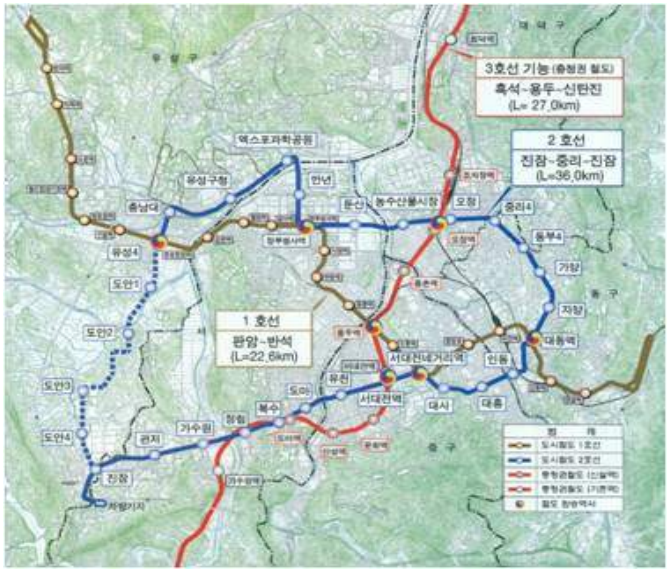

Figure 9. Route Map of Daejeon Metro Line 2
(Blue Line, Solid Line – Phase 1, Dotted Line – Phase 2)

Figure 10. Daejeon Metro Line 2 in Downtown Area

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