Status of development of the segmented 3 way Maglev switch and running tests

Jong-Min Lee, Hyung-Suk Han, Chang-Hyun Kim, and Hyeon-Jae Shin
Korea Institute of Machinery and Meterials Dept. of Magnetic Levitation and Linear Drive, Daejeon 305-343, KOREA
lee_jm@kimm.re.kr, hshan@kimm.re.kr, chkim78@kimm.re.kr, godnow@kimm.re.kr

Hyo-Jung Cha, and Hun Kim
Korea Rail Network Authority KR Research Institute Headquarters New Transit System Division, 264 Shinan-Dong Dong-Gu D Daejeon 300-731, KOREA
angel0418@hanmail.net , samosail82@naver.com

ABSTRACT: Development of the segmented Maglev switch is one of processes for the urban Maglev vehicle, which is scheduled to debut at the end of 2012 in Incheon international airport. The segmented 3 way Maglev switch is composed of 3 moving girders, 4 fixed girders, driving units, transfer units, clamping units, and articulation relieving equipment etc. In this paper, the measured results on the interaction between vehicle and switch are discussed. The measured results are following; First, consecutive moving test and natural frequency for girder and levitation rail. Second, lateral air gap of vehicle running on switching interval. Third, noise according to movement of 3 way segmented switch. Forth, thermal transformation of girder according to temperature changes. With over the measurement results, more reliability and stability of 3 way segmented switches are secured.

1 INTRODUCTION

Maglev commercialization program that started under the supervision of MLTM (Ministry of Land, Transport and Maritime Affairs) in Dec. 2006 has been carried out, and the program decided to construct demo-line for Maglev vehicle around Inchon airport in 2007. The demo-line is 6.1km long double track as shown in Figure 1. Now an installation routine of PSC girder is in progress.

Figure 1. Air view of demo-line for Maglev vehicle

Switch system is surely needed in demo-line when a path of the vehicle is changed and the vehicle enters or exits from the station. Switches which is going to be installed in demo-line are following: 2 groups of 2 way switch, 4 groups of 3 way switch, 2 groups of crossing switch with two of 2 way switch, a group with a 2 way plus a 3 way crossing switches and a scissors switch.

In this program, the segmented 3 way switch and a scissors type switch were developed, and various tests were carried out to verify the safety and reliability at KIMM's test track. In this paper, the development status of segmented 3 way switch which was developed first in Korea and the results from performance tests are discussed.

2 A SEGMENTED 3 WAY SWITCH

2.1 Structure of the 3 way segmented switch

The switch for Maglev vehicle has the structure as a shape of box girders as shown in figure 2. Here, to satisfy the required linearity, limited deflection and

stiffness of girder, the length of the switch should be long and its weight should be heavier. Hence, girder may have the complicated structure as the bigger driving and clamping devices are needed.

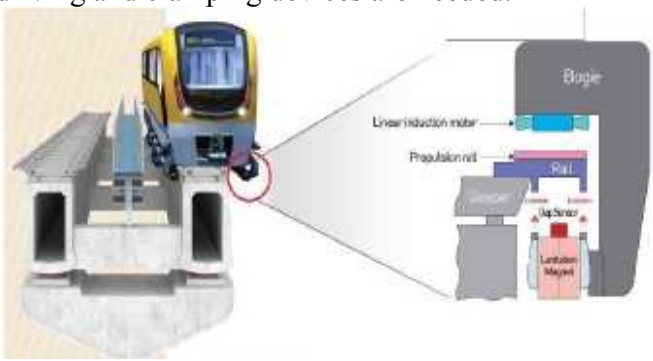


Figure 2. Structure for bogie of Maglev vehicle

2.2 Composition of the 3 way articulated switch

Figure 3 shows the segmented 3 way switch which is composed of girders, driving unit, transfer unit, clamping device, articulation angle relieving equipment, and connecting unit at ends. The switch weighs about 40 ton, and its switching time must be less than 20 seconds.

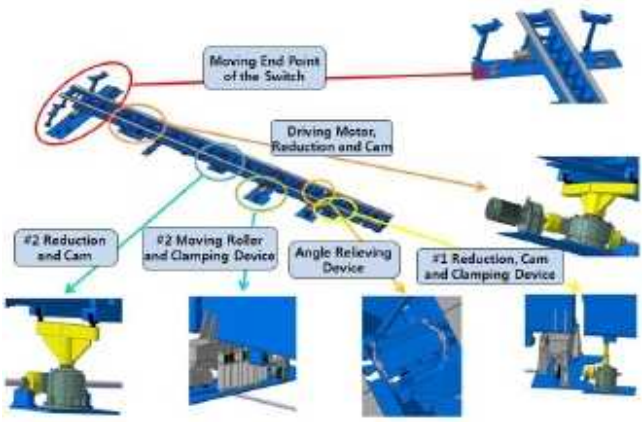


Figure3. Composition of 3 way articulated

2.2.1 Switching girder

The 3 way moving girder is composed of fixed girders at start and end point, 2 short span girders and 1 long span girder. Switching girders are 1.4 m high and type of box girder. The levitation and driving rail is installed on the top of girder to react with electromagnet and linear induction motor. An articulation angle between neighboring moving girders is 2.3 and each girders generates the curvature.

2.2.2 Driving unit

Figure 4 shows the driving unit which is applied to the long span girder. That is composed of driving motor, gear reducers, cam guide, and cam bar which is linked to each reduction gear. The motor speed is reduced by 1/300 through the gear reducers, and it lets the long span girder move the 2.7m in 7 second. The gear reducers are connected with the short span girders and each gear reducers is linked on the same axis so that each operates altogether simultaneously.

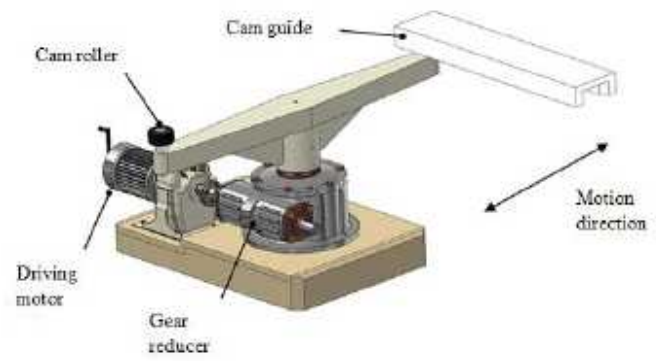


Figure4. Composition of driving device

2.2.3 Clamping device

The function of the clamping equipment as shown in Figure 5 forces mechanical constraint to the switch system when the moving girders stop. Therefore it restricts the movements in order to prevent vibration due to unfixed apparatus while Maglev is running. Three clamping units are installed to the moving girders of the switch.

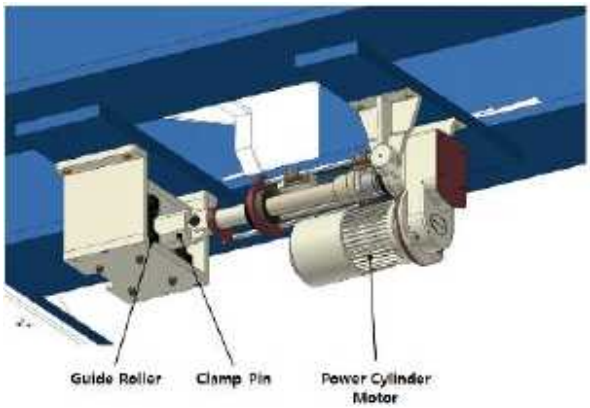


Figure5. Composition of clamping device

2.2.4 Angle relieving equipment

The running stability of Maglev is mainly affected by articulation angle of the segmented switch. It is

needed to decrease the lateral air gap at the rail joints of the levitation rail when the car passes through the switching interval. To reduce the articulation angle of the levitation rail, the angle relieving equipment is installed at the upper side of segmented point of the switch. An articulation angle of the switch is determined 1.5 and the total six of angle relieving equipments are applied to the switch.

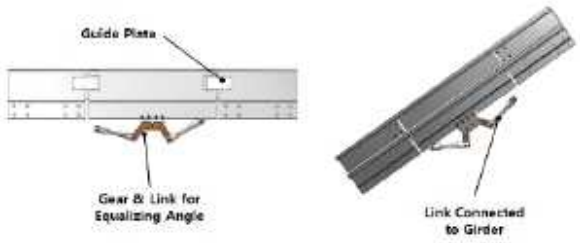


Figure6. Composition of angle relieving device

2.2.5 Connecting unit at ends

To calibrate fixed parts and difference between rail levels at ends during installation, and control relative height when the deformation occur later, connecting unit at ends which is hinge structure of cantilever shape is applied.

3 TEST RESULTS

Figure 7 shows the picture of Maglev vehicle running on the segmented switch. To verify the performance and secure the reliability, consecutive performance test was carried out a million times. Furthermore, tests on the running safety through calculation of girder deflection, thermal expansion, natural frequency, lateral air gap, and response control were carried out when Maglev runs on the segmented switch.

Figure7. Maglev vehicle running on the segmented switch

3.1 Consecutive performance test

Consecutive performance test was carried out in twice. The production Company Daemyung was carried out 420,000 times, and improved unreasonable mechanical system. Next, test of 520,000 times was carried out from end of 2009 to January 2011 at KIMM's test track. Through the test, a proximity sensor which checks position is employed, and the clamping unit is improved by the structure which constraints completely the joint pin in vertical and parallel position. And the hinge structure of connecting unit at ends is improved to minimize the deflection at end of cantilever. Also, life evaluation of a power cylinder which is driver of clamping unit is carried out according to the number of performance, and the way for noise reduction is established according to the shape and installed angle of carrier rollers.

3.2 Thermal expansion measurement

To calculate a thermal expansion of the switch girders, a measuring instrument and monitoring system are prepared as shown in Figure 8, and a measuring instrument is arranged as shown in Figure 9, to measure thermal expansion in longitudinal and vertical direction. The used instruments are following: BI-LTEM100, PC, MONITOR, LVDT, THERMOCOUPLE, and THERMOMETER.

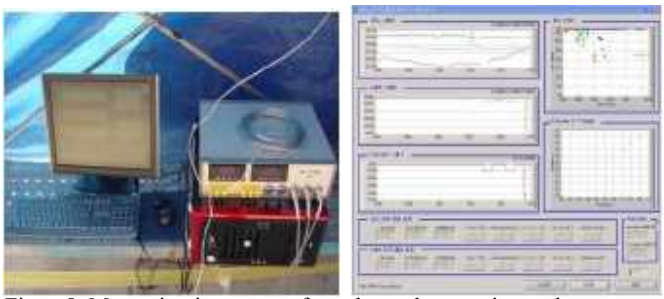


Figure8. Measuring instrument for a thermal expansion and monitoring system

Figure9. Installation of measuring instrument for a thermal expansion about longitudinal and vertical directions

An analysis on a thermal expansion in longitudinal direction was carried out when temperature set 60 C. As a result, the thermal expansion coefficient is $12 \times 10^{-6}/°C$. An actual measurement was carried out at 30 C , the results is shown in Figure 10. The mean value of thermal expansion coefficient is $5.8 \times 10^{-6}/°C$, and comparing that with the thermal expansion coefficient from analysis, test result is half value of analysis, which implies that the clearance limit is enough as the interference between fixed girder and end part of moving girder is not occurred.

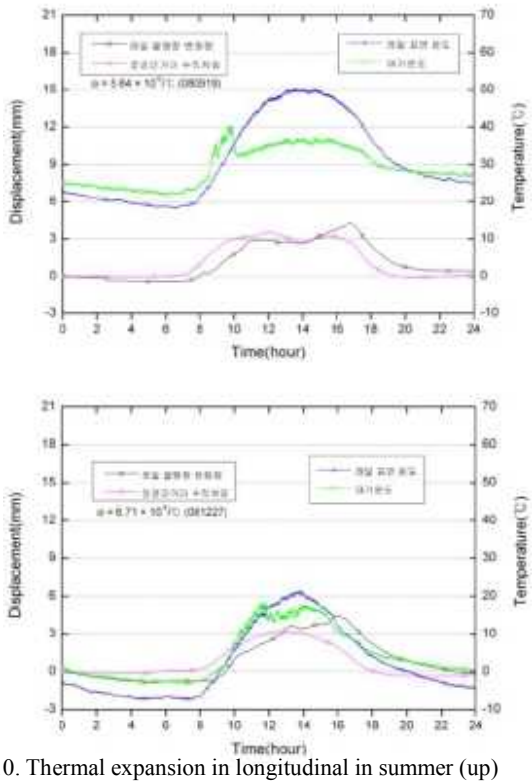


Figure10. Thermal expansion in longitudinal in summer (up) and winter (down)

3.3 Natural frequency measurement

The natural frequency for the switch girders and the electromagnet was calculated. Figure 11 shows the first natural frequency and modal analysis for the long span girder. The results from modal analysis and impact test for the moving girders are arranged as shown in Table 1. As shown in Table 1, the results of the test are in accord with the results of analysis. The first natural frequency of each short moving girder is 309.18 Hz for the first girder and 301.26 Hz for the second girder, it is surely stated that the resonance would be not occurred because the natural frequency for the short moving girders is much higher than 7 Hz for bogie. Also, 11.66 Hz from the test and 13.63 Hz from the analysis for the long span girder are higher than the natural frequency for bogie. The possibility of the resonance is remote.

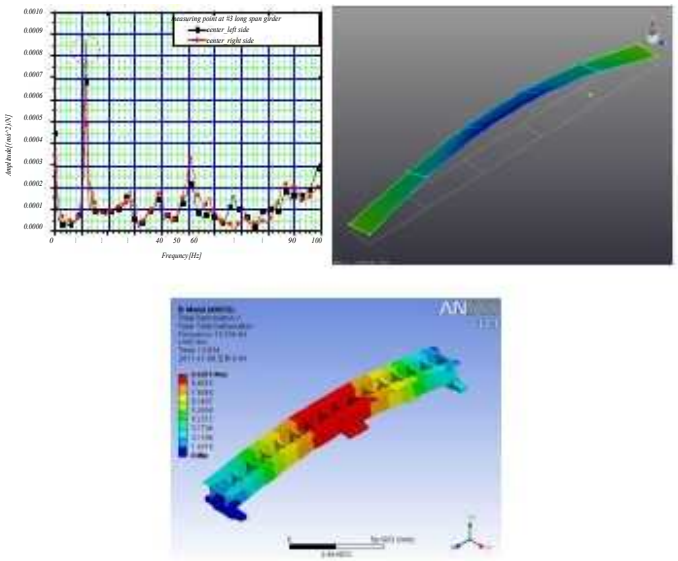
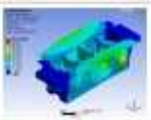
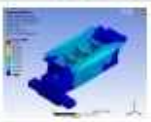
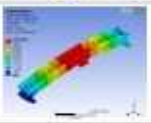
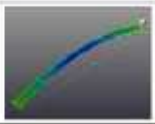


Figure11. The natural frequency and modal analysis for the long span girder

Table1. The modal analysis and test for the moving girders

	Modal analysis		Impact test	
	Natural frequency (Hz)	Mode shape	Natural frequency (Hz)	Mode shape
1st girder	309.18		293	
2nd girder	301.26		286	
3rd girder	13.63		11.66	

3.4 Girder deflection measurement

The guideway deflection for the moving girders is calculated when the empty vehicle which weighs 20kN/m passes through the switch. For calculating the deflection, gap sensors are installed at the center of each moving girder, and the speed of the vehicle is limited at 5km/h and 10km/h. Figure 12 shows the guideway deflection at 5km/h and 10km/h respectively. The guideway deflection for 3rd long span girder is 3.73mm at the speed of 10km/h. Therefore it is predicted that the guideway deflection

would be about 5mm when the full vehicle runs, as an applied force for the deflection is the linear function and the full vehicle is 1.3 times as heavy as the empty one.

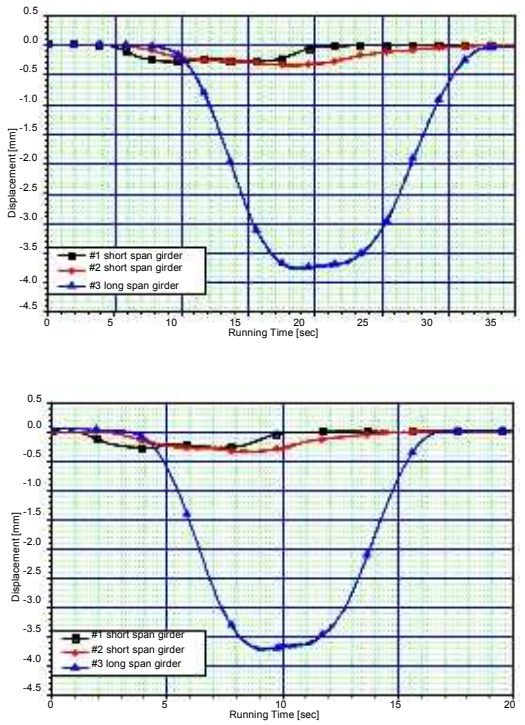


Figure12. The guideway deflection for girders at the speed of 5km/h (up) and 10km/h (down)

4 CONCLUSION

It is the switch system that the possibility of an accident is most high of guideway system for Maglev, even the wheel on rail system accident is often occurred at the switch. Therefore, the switch should have a precise movement and reliability. To do that, Development of precise and reliable switch which is one of Maglev Commercialization Program is being carried out. Recently, a consecutive performance test and calculation of girder deflection, thermal expansion in longitudinal and vertical direction, natural frequency, lateral air gap, and response control are carried out. It is believed that the stability of the switch is verified through the evaluation of the reliability of movement, deformation of girders and the possibility of the resonance resulting from analysis and tests. Now, the scissors type switch which is the center interval between rails is 6m long is developed based on development of the segmented 3 way switch after supplementing efficient movement and noise reduction. It is expected that development of the segmented 3 way switch and scissors type switch play adequate roles for urban transportation.

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