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Parameter characteristics of rail inspection measurement system of HSR-350x †

Sang-Soo Kim*, Choonsoo Park, Young-Guk Kim and Chankyoung Park

High-Speed Rail Engineering Corps, Korea Railroad Research Institute, Uiwang, 437-757, Korea

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Abstract

The Korean Train Express (KTX) has opened to commercial traffic since 2004 at a maximum speed of 300 km/h. As the train goes faster, it is necessary to inspect and maintain the rail regularly to secure the safety and reliability of the high-speed railway. The track irregularities can affect the running behavior of the train, the riding comfort of passengers, and the safety of the running train. To prevent undesired effects of rail irregularities, it is necessary to inspect the status of the rail regularly. Fast and accurate measurement result is the key role of the rail measurement system. The authors contrived the high-speed rail measurement system with a maximum measurement speed of 320 km/h and installed it into HSR-350x. The Korea High-speed Railway (HSR-350x) was developed and is being tested. The track irregularity inspection module for HSR-350x was designed and constructed over 300 km/h. A real test run on the high-speed rail was then performed. In this paper, we introduce the track irregularity inspection system and the measurement system of HSR-350x. A test run to verify the reliability of the system is performed and the result shows good performance of the track inspection measuring system.

Keywords: High-speed railway; Measurement; Signal processing; Track irregularity

1. Introduction

In Korea, the Korean Train Express (KTX) has been commercially operating and achieving the increase of the volume of traffic since 2004. The maximum speed of KTX is 300 km/h and KTX runs on the high-speed rail. To secure the safety and reliability of the high-speed railway, it is necessary to inspect and maintain the rail regularly. Until now the maintenance of high-speed rail is being performed based on the measurement results of the rail measuring car. The maximum speed of the rail measurement car is under 160 km/h and the rail measurement car inspects the restricted high-speed rail once a month.

By the way, the Korean High-speed Railway (HSR-350x) was developed by the National R&D project of the Ministry of Construction & Transportation. It has been on trial run on Kyung-bu high-speed line and achieved 350 km/h on increasing speed test in 2004. HSR-350x has over 400 sensing channels and it has monitored and saved the data during the test run. The authors installed the high-speed track irregularity measurement system into HSR-350x and combined the measurement system. The track irregularity measurement system has 0.25 m sampling distance and can work at 320 km/h theoretically [1].

HSR-350x is composed of seven cars; two power cars, two motorized cars and three trailer cars. The attachment of the suggested system was performed in July 2007. The measurement items of the system are the longitudinal level irregularity, the cross-level irregularity (including the cant), the gauge irregularity, the alignment irregularity, and the twist irregularity. The speed is also measured in two ways; one is the

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*Corresponding author. Tel.: +82 31 460 5625, Fax.: +82 31 460 5649
E-mail address: sskim@krri.re.kr

use of the encoder attached at the axle, and the other is the use of the global positioning system (GPS).

The test is being performed in high-speed line and the analysis of each data resu is progressed after the test. And the maximum speed test of the measurement was performed and succeeded the rail inspection at 320 km/h. This is the fastest record of the real train test over the world. The application of the suggested method to real rolling stock is the first case in Korea. The results of the tests yield better track measurement information data compared to the conventional rail measurement car. Moreover, it shows the possibility of the new method being used as the track irregularity measurement system for Korean high-speed rail maintenance.

2. Track irregularities measuring system

2.1 Types of track irregularities

The condition of the rail track is an important factor when the train runs. It affects the running behavior, safety, and riding comfort of the passengers. It is necessary to inspect the status of the track and to detect flaws in the rail as the speed of the train increases. The types of the track irregularities can be classified into five types [2, 3].

The track gauge is defined as the distance between the gauge faces of the two adjacent rails and it is measured 14 mm(Zp) below the running surface. It is shown in Fig. 1. The standard track gauge of the Korean high-speed rail is 1435 mm.

Longitudinal level is defined as the evenness or uniformity of track in short distances along the top of the rails. Under load, the track gradually deteriorates owing to the dynamic effects. Irregularities of the rail surface are measured by the vertical accelerometers, optical point, and roll rate gyro.

Cross level is defined the difference in the height of running surfaces of the two rails. It is expressed as the height of the vertical leg of the right-angled triangle having a hypotenuse that relates to the nominal track gauge.

Track alignment is defined as the local variation in the curvature of each rail of track. On tangent track, the intended curvature is zero, and thus the alignment is measured as the variation or deviation from zero. In a curve, the alignment is measured by the lateral accelerometer, yaw rate gyro, and horizontal optical point.

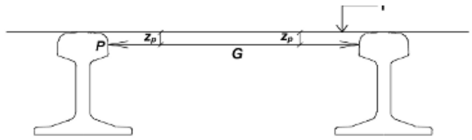


Fig. 1. Track gauge.

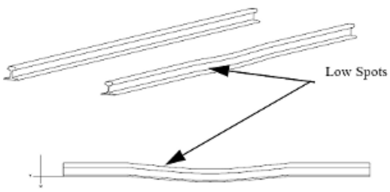


Fig. 2. Longitudinal level.

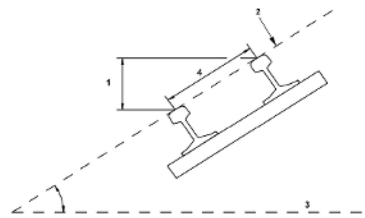


Fig. 3. Cross level.

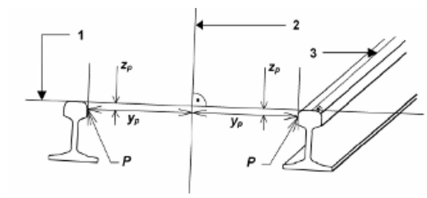


Fig. 4. Track alignment.

2.2 Measurement method

The measurement system is composed of lasers, cameras, and inertial tools. It determines the spatial position of a measuring sensor by double integration of acceleration transducers. The sensors, namely, lasers, cameras, and inertial transducers, are installed into the frame of the bogie and move together as shown in Fig. 5.

The block diagram of the track measurement system is shown in Fig. 6. The signal process of the system is divided into time domain and space domain. First, raw data from the sensor and distance from the tachometer are inputted and these data are filtered by internal synchronization signal. Then time-arranged data are resampled from time base to distance base, and each track parameters are calculated and outputted.

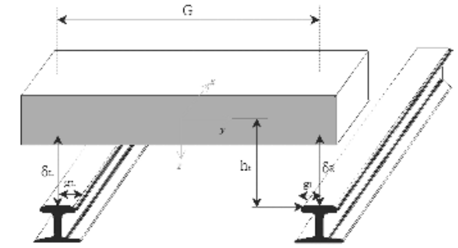


Fig. 5. Principle of track measurement system.

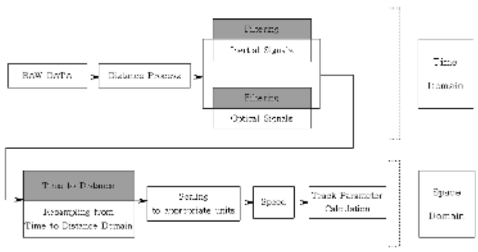
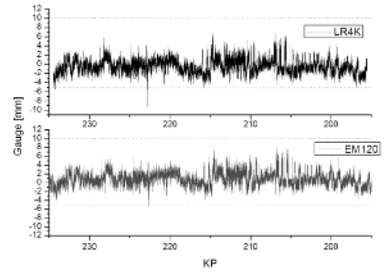
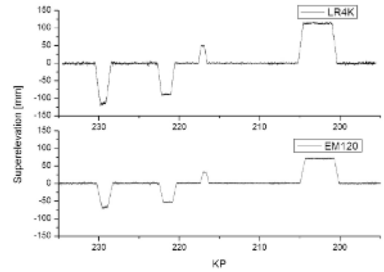


Fig. 6. Track measurement processing flow.

Fig. 7. The feature of HSR-350x.



(a) Track gauge



(b) Cross level

Fig. 8. Track gauge and cross level.

The high-speed rail irregularity measurement system was manufactured and installed in bogie #5 between TT2 and TT3 of HSR-350x, which was developed by National R&D project and is shown in Fig . 7.

3. Rail irregularities measurement tests

The rail irregularities measurement tests have been performed on the commercial high-speed line since July 2007. Some parts of the analyzed data are discussed in the following sections.

3.1 Track gauge and cross level

Track gauge and cross level have no different frequency characteristics so they have a relatively simple algorithm to calculate. To evaluate if these results are resonable or not, we compared their data with other results from another rail measurement system, EM120. EM 120 is a rail measurement vehicle that uses three chords method with maximum measurement speed of 120 km/h. The measurement results of the same line and day, are shown in Fig. 8: (a) indicates the track gauge and (b) is the cross level. Black lines are the results from the suggested measurement system and red lines are those from EM 120. Thetrack gauges from the two systems have similar patterns and values. And the cross levels indicate geometry cant with the same position although the cant value is somewhat difference. After test, field investigation of the cants was performed and it was found the result of the suggested system was more accurate.

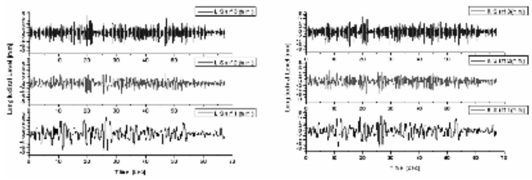
3.2 Longitudinal level and track alignment

Longitudinal level and track alignment have a similar process to achieve the measurement value. These parameters indicate the shape of the rail, and they are analyzed according to several wavelengths in space domain as shown in Table 1. D3 is the short wavelength, D2 is the middle wavelength, and D1 is the long wavelength irregularity respectively. The track irregularity measurement system has 0.25 m sampling rate and the measured data are analyzed in the space domain. The results of longitudinal level and track alignment are shown in Fig. 9 and Fig 10, respectively at 300km/h. Further, (a) is the result of time response, which has 0.25 m distance sampling and (b) is that of frequency response. Black lines are frequency analysis results of D1, red lines are those of D2, and blue lines are those of D3. The left ones are the results of the left rail and the right ones are those of the right rails toward the north.

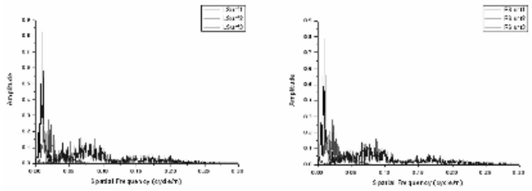
As shown in Figs. 9 and 10, each parameter has its own bandwidth and the long wavelength irregularities are dominant.

Table 1. Wavelength ranges of parameters.

Parameter	Wavelength Range	Spatial Frequency
Surf D3	3m<λ ≤ 25m	0.04< f ≤ 0.3
Surf D2	25m<λ ≤ 70m	0.014< f ≤ 0.04
Surf D1	70m<λ ≤ 150m	0.0007< f ≤ 0.014
Align D3	3m<λ ≤ 25m	0.04< f ≤ 0.3
Align D2	25m<λ ≤ 70m	0.014< f ≤ 0.04
Align D1	70m<λ ≤ 200m	0.0005< f ≤ 0.014

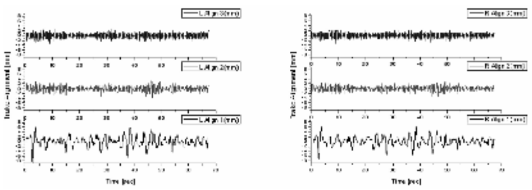


(a) Time response

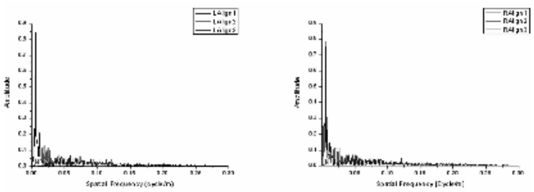


(b) Frequency response

Fig. 9. Longitudinal-level measurement results.



(a) Time response



(b) Frequency response

Fig. 10. Track alignment measurement results.

4. Conclusions

In this paper, we introduced a high-speed measurement system and installed it into HSR-350x and analyzed the test run result on high-speed line. Through this research, we can conclude the following:

- The high-speed rail measurement system is successfully installed into HSR-350x and operated over 300 km/h.
- Each measurement parameter has its own characteristics and good reliability.
- It is certified that the rail irregularity measurement system can fully exhibit its performances at 300km/h.

This rail irregularity measurement system is being tested on commercial line and the data are accumulated by HSR-350x. Future studies will involve the analysis of the relation between the rail irregularities and the behavior of train, and rail condition histories by repeated measurement.

Acknowledgment

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Sang-Soo Kim received his B.S. degree in Mechanical Engineering from Chung-buk National University, Korea, in 1996. He then went on to receive his M.S. and Ph.D. degrees from Ibaraki National University, Japan, in 1999 and 2002 respectively. Dr. Kim worked as a researcher of mechatronics group at the Akita Research Institute of Advanced Technology (AIT) from 2002 to 2004 in Japan. He is currently working as a senior researcher at the Korea Railroad Research Institute (KRRI) in Korea. Dr. Kim's research interests are in the areas of test evaluation, system engineering, and vibration control of high-speed railway.