Abstract

To implement track measurement using an in-train-set car when commercial passenger transport service begins along the entire Kyushu Shinkansen Kagoshima route after its opening, the Kyushu Japan Railway Company (JR Kyushu) has manufactured a prototype track measuring device to be mounted on the confirming car. The measuring device applies the inertial mid-chord offset method, originally developed by the Railway Technical Research Institute (RTRI). In adopting the prototype measuring device developed for this purpose by the RTRI, we improved its construction to prepare for installation on a car used for passenger transport service, implemented ways of eliminating measurement errors observed in trial tests, and is now performing endurance testing in a main line section already in operation. As a result, we have proved that this system can measure track irregularities in a stable manner. It is expected, therefore, that track inspection using commercial railway vehicles with the inertial mid-chord offset method on train sets in revenue operation will enable frequent monitoring of track conditions and significantly cut track maintenance costs.

1. Introduction

To implement track measurement using an in-train-set car when commercial passenger-transport service begins along the entire Kyushu Shinkansen Kagoshima route after its opening, the Kyushu Japan Railway Company (JR Kyushu) has manufactured a prototype track measuring device to be mounted on the confirming car. The measuring device applies the inertial mid-chord offset method (1), (2), originally developed by the Railway Technical Research Institute (RTRI). This paper outlines the newly developed track measurement system now under endurance testing in the already-opened Shin-Yatsushiro - Kagoshima Chuo main line section of the Kyushu Shinkansen.

2. Development of the prototype track measurement device by the inertial mid-chord offset method (3), (4)

The prototype track measurement device has been developed according to the following concepts:
* Installation on the trucks of the Series 800 cars in Kyushu Shinkansen trains
* Simplification of coupling/de-coupling operation for the measuring unit to/from train sets
* Guarantee of stable performance by implementing only a heat run after turning on the power-source switch

The measuring unit (with dimensions W = 1,720 mm, H = 225 mm and B = 320 mm) incorporates an accelerometer, a two-axis rail displacement meter, a gyroscope and a substrate. The cubicle is made of aluminum to make it lightweight, and as a result the total weight of the measuring unit is suppressed to about 100 kg. A difference in level of 25 mm is set at the center of the measuring unit's top surface to guarantee free movement of the pin connecting the truck and the carbody. The measuring unit's bottom surface is designed with a height of 120 mm from the rail level in consideration of the maximum wheel wear and the rolling stock gauge. To detect the target for receiving position information at intervals of 500 m, a photoelectric sensor is installed on the side at the center of the measuring unit. (Fig.1)
3. Composition of the prototype track measurement device

At the planning stage, we investigated the idea of installing a sensor unit on the truck frame to measure the relative displacement between the rail and the sensor unit using a displacement sensor, a gyroscope and an accelerometer, while using an onboard processing unit to control the sensor and calculate its output. However, the accelerometer outputs low-voltage analog signals that are susceptible to the noise of traction motors. It was anticipated, therefore, that the measuring precision would be adversely affected if a system incorporating this accelerometer were used for Kyushu Shinkansen trains that are exclusively composed of traction motors. We therefore composed a track measurement device with four components: a measuring unit, a relay box, a power-supply and conversion unit and a personal computer for data processing/recording (see Fig. 2 for the device composition). The measuring unit incorporates part of a processing circuit to amplify the accelerometer output to a voltage overwhelmingly higher than the noise of traction motors. The relay box is designed to convert the data output from the measuring unit to optical digital signals for noise-free transmission through an optical fiber line to the power-supply and conversion unit.
4. A running test to check the track measurement device for precision

We mounted the track measurement device thus prepared on a confirming car and ran it at the Kyushu Shinkansen’s Izumi maintenance base to check the system for precision. Figure 3 shows the waveforms measured when the confirming car ran on Shinkansen crossing No. 9 and the curve incident to it in this running test. When the rail displacement sensor detected a waveform error at a gap in the crossing, its effect emerged in a 5 m-long section with the error occurrence point at its center as an effect of filter processing to restore a chord of 10 meters waveform. This means that the track inspection in this running test was performed at different car speeds, which were suppressed, however, to a little over 20 km/h to observe the speed limit on the turnout. Despite such disadvantageous conditions for the measurement (low and non-constant speed), the track irregularity data was almost all obtained correctly except at the said gap in the turnout. After this verification process, we started a running test with the device mounted on a confirming car on the main line in the end of October 2006. About one year later, the cumulative running distance had exceeded 20,000 km, with track irregularities having been measured about 200 times.

![Fig.3 Results of alignment in running tests by prototype device](image)

5. Evaluation of the endurance-test results

Figure 4 shows the waveforms measured once each month for the last three months at a 12‰ up-gradient section with a curve radius of 4,000 m. These three waveforms are in good agreement without presenting errors due to accelerometer cross-talk, which has been an important problem anticipated in gradient sections. The precision of measurement is notably high with low reproducibility errors recorded, in that the waveforms of longitudinal level were $\sigma = 0.15$ mm (maximum 0.53 mm) and the waveforms of alignment were $\sigma = 0.11$ mm (maximum 0.60 mm). The device has been subjected to regular inspections (at every about 10 days and a month, three months, six months and a year) that observed no abnormalities such as loosening of screws in the measuring unit, damage to connectors, deterioration of driving parts around the servo motor or settling of the vibration-preventive rubber used to connect different components. During the endurance test, however, the waveform was disturbed once, presumably due to instantaneous dew condensation on the laser-beam-projecting/receiving window caused by changes in the ambient temperature when the confirming car moved from a tunnel into an open section in high-humidity conditions. We plan to investigate this phenomenon and reflect the study results in designing a practical track measurement device using cars in commercial service, together with the results of endurance testing in the future.
6. Conclusion

Track measurement using commercial railway vehicles with the inertial mid-chord offset method on trains in passenger service enables frequent monitoring of track conditions and significantly cuts track maintenance costs. The newly developed prototype track measurement device, which is designed for installation on a confirming car, can be re-mounted on most of the motorcars used for maintenance by JR Kyushu. It is therefore thought that the device will be extremely effective for track measurement in the case of a large-scale disaster. We will reflect the results of ongoing endurance testing in the design of the system for installation on trains in commercial service, thereby aiming to further improve its precision and reliability.

References