Study on the Application of an Axle Box Heating Detection System to Cold Regions

An axle box heating detection system completed in fiscal 2008 is being deployed for major line sections in the greater Tokyo area. As there is demand for this system in regions with heavy snowfall too, we examined functions for cold and snow resistance and developed an axle box heating detection system for cold regions. Bench tests and field verification of cold and snow resistance performance of the developed system proved that the system could work correctly to measure temperature of axle boxes at the level of snow cover seen in the winter of 2010 - 2011.

Keywords: Axle bearing, Axle box, Temperature detection, Temperature sensor, Snow cover, Snowfall

1 Introduction

The axle box temperature heating detection system was developed for early detection of abnormal heating of components of axle bearings—important running devices for railway rolling stock—so that critical accidents could be prevented. The developed system is now being deployed for major lines in the greater Tokyo area. Early detection of abnormality of bearings is needed in regions with heavy snowfall too, so we examined functions for cold and snow resistance to apply the system for the greater Tokyo area to cold regions. We installed a prototype system that reflected the examination results at Ugo-Ushijima Station on the Uetsu Line (in Akita City) in the period from December 2010 to September 2011. Using that, we investigated the effects low temperature, snow cover, and snowfall have on performance.

2 Development for System for Cold Regions

The developed system measures temperature of components of an axle box that holds bearings. Specifically, it is a system using contactless infrared temperature sensors (infrared radiation thermometers) installed facing axle boxes of running train cars as shown in Fig. 1. The system measures surface temperature of axle boxes obliquely from below, and it gives an alert if it detects that a designated temperature is exceeded. Wheel detectors that are installed on the rail determine the position of each axle box. By using three wheel detectors on each side, velocity of passing trains is calculated to identify the position of the axles.

The system has a built-in heater to keep ambient temperature at 5 ºC or higher for stable operation of temperature sensors. As the sensors are an infrared type, there should be no obstacles between the system and the axle box to be measured. Furthermore, to apply the current system to cold regions, cold and snow resistance has to be enhanced. Taking into account those conditions and installation to lines along the coast of the Japan Sea (Uetsu Line and Ou Line), we set the following specification values for cold regions based on weather data in the previous five years at Niitsu, Akita, Odate and Hirosaki.

- Cold resistance: Lowest operation temperature -20 ºC
- Snow resistance (snow cover): Largest snow depth 75 cm
- Snow resistance (snowfall): Heaviest snowfall 40 cm/day

Fig. 1 Overview of Axle Box Heating Detection System

2.1 Snow Resistance Test (Snowfall)

To see the effect of snowfall, we carried out snowfall simulation tests using actual snow and a screen (Fig. 2). In the test, we found some distorted waveforms of temperature measured with the temperature sensor caused by snowfall blocking the infrared light path. The test results, however, confirmed that the system did not make incorrect detection of temperature as being higher than actual temperature, even in snowfall of the simulation test level where accurate measurement was difficult because around 10 - 30% of the infrared light was shadowed (Fig. 3).
2.2 Snow Resistance Test (Snow Cover)

To see the effect of snow cover, we installed a temperature sensor unit for the greater Tokyo area and an electric snow melting mat in the yard of the Odate Transport Depot (Odate City, Akita Prefecture, Fig. 4) and carried out snow resistance tests. The test results proved that snow on the front side of the unit could be melted even in snow cover of approx. 20 cm.

The window for the infrared sensor is located on the top of the unit for the greater Tokyo area, but we found it could be covered with snow. We thus decided to move the window to the side surface on the track side (Fig. 5). We also improved the heater as a measure against low temperature.

2.3 Cold Resistance Test

To check cold resistance performance, we installed a controller unit and temperature sensor unit, each with a heater, in a thermostatic chamber set at 20 ºC and carried out continuous operation testing for 25 hours. The test results proved that the temperature in each unit was kept at 5 ºC or higher and both units continued operating. The electric power of the heater required for the controller unit was found to be approx. 400 W (Fig. 6).

2.4 Second Snow Resistance Test (Snowfall)

In order to quantify the snowfall simulation test results of section 2.1, we carried out snow resistance tests again at the Shiozawa Snow Testing Station of the Railway Technical Research Institute (Fig. 7). No distorted waveforms were observed under the test conditions this time (snowfall intensity "strong": 3 cm/h or more). However, we decided to further conduct field verification tests because snow quality varies by location.
3 Field Tests

3.1 Installation of the Prototype System

Based on the results of prior verification, we produced a prototype system with changes in the location of the sensor window and the power of the heater, and we installed that at Ugo-Ushijima Station for the field test. System configuration and photos of installation are shown in Fig. 8. Since the test location was in a single-line section, we installed temperature sensors at an angle of 90° to the rail too to check if there was any difference according to train running direction. Those sensors would be installed at 45° to the rail in the greater Tokyo area. We also changed the wheel detectors to models with a heater and moved those from the inside of the rail (flange side) as they are located in the greater Tokyo area to the outside of the rail (rim side) where less effect of snow cover would be expected.

Weather data of Akita City in 2010 - 2011 winter was as follows.
- Lowest temperature -7.1 ºC (January 16 and 27, 2011)
- Deepest snow cover 43 cm (February 11, 2011)
- Heaviest snowfall 19 cm/day (February 10, 2011)
(Source: website of the Japan Meteorological Agency)

Fig. 9 shows a train actually in operation passing the prototype system. The field tests demonstrated that the prototype system could make stable measurement for passing trains too, while the system for the greater Tokyo area measures temperature when a train enters a station to stop there. Almost no difference in measured temperature according to train running directions was observed either.

Fig. 8 Prototype System Installed at Ugo-Ushijima Station

Fig. 9 Example View of Train Passing Prototype System
3.2 Test Results for Snow Cover

Fig. 10 shows the test site on February 11 when the deepest snow cover that winter was observed. We were able to confirm that the snow in front of the temperature sensor unit was melted by the snow melting mat and that the infrared light path was secured.

3.3 Test Results for Snowfall

To see the effect of snowfall on temperature measurement, we checked the waveform data of the temperature sensor. Fig. 11 shows the test site on February 10 when the heaviest snowfall of that winter was observed. Due to intense snowfall, the snow melting mat was temporarily covered with snow, but we were able to confirm that the infrared light path for the sensor was still secured.

3.4 Test Results for Low Temperature

For cold resistance performance of the prototype system, we checked the temperature in the controller unit and the temperature sensor unit in the test period including January 16 and 27 when the lowest temperature in that winter was observed. The results confirmed that the temperature could be kept at 5 °C or higher. No malfunction of the prototype system due to low temperature occurred in the test period.

4 Conclusion

As introduced above, we improved the axle box heating detection system for the greater Tokyo area to adapt it to cold regions. We then installed the prototype system in Ugo-Ushijima Station and carried out tests in winter. The test results confirmed that the measures against low temperature and snow functioned as expected and that the overall system including the temperature sensors and the controller unit worked correctly under the conditions of the 2010 - 2011 winter.

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