Development of an L-Shaped Guide to Prevent Deviation from Rails

The derailment of a 200 series Shinkansen train in the Mid Niigata Prefecture Earthquake of 2004 was the first derailment ever of a Shinkansen train in service. In this derailment, however, the damage was kept to a minimum because the lead car life guard and the wheels straddled the rail, and the cars stopped without deviating greatly from the rails.

Large deviation of cars from the track must be prevented to limit the extent of damage in case of derailment of Shinkansen cars in incidents such as earthquakes. We have therefore developed an L-shaped guide to prevent deviation from rails by controlling (large) lateral displacement of cars.

In this development, we studied structure dimensions and shape, checked strength by FEM analysis and load tests, and conducted tests using a bogie testing machine and active duty car. Through those, we successfully confirmed that the developed guide would have no problems in terms of strength and would not affect bogie performance. Based on the results, the L-shaped guides to prevent deviation from rails have been installed to all train sets of Shinkansen trains in service.

Keywords: L-shaped guide to prevent deviation from rails, Life guard, FEM analysis

1 Introduction

In the Mid Niigata Prefecture Earthquake of October 23, 2004, a 200 series Shinkansen train derailed, marking the first derailment ever of a Shinkansen train in service. In this derailment, however, every car of the train set stopped without large deviation from rails because the lead car life guard and the wheels straddled the rail, preventing the lead car from deviating much from the track. Fig. 1 is a photo of the lead car of the derailed 200 series Shinkansen train and Fig. 2 shows the life guard and the wheels straddling the rail.

We therefore decided to develop a guide that prevents large deviation from rails by Shinkansen cars even in derailment in incidents such as earthquakes (L-shaped guide to prevent deviation from rails, or “L-shaped guide”).

In the development, we studied the shape and dimensions using drawings and strength using numerical analysis. We also evaluated strength and effect on bogie performance in stationary tests using prototype guides and in running tests using an active duty car.
2. Development Overview

2.1 Shape

2.1.1 Size and Structure

The L-shaped guide must fit into the rolling stock clearance. So, we adopted the structure where the guide is attached on the bottom surface of the bogie axle box to control lateral displacement of the car.

The height and width of the L-shaped guide was determined based on the relative position to the rail fastener and the rolling stock clearance.

The major specifications of the L-shaped guide are shown in Table 1, the deviation prevention action of that is illustrated in Fig. 3 and the appearance in Fig. 4. When a wheel derails, the guide on the bottom of the axle box contacts the side of the rail and limits (controls) further lateral displacement.

The L-shaped guide will demonstrate better performance when used along with the rail rollover prevention device that we separately developed.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Dimension</td>
<td>Approx. 150 mm (H) X 170 mm (W) X 230 mm (D)</td>
</tr>
<tr>
<td>Weight</td>
<td>8.6kg</td>
</tr>
<tr>
<td>Material</td>
<td>Special alloy steel</td>
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</tbody>
</table>

Table 1 Specifications of the L-Shaped Guide to Prevent Deviation from Rails

2.1.2 FEM Analysis*

In the production of the L-shaped guide, we carried out FEM analysis to check the strength of the planned shape. Fig. 5 shows an example of the FEM analysis results for the L-shaped guide for existing cars. The analysis results clarified that a structure could be formed with no problems in terms of strength in relation to the force expected to be generated between the L-shaped guide and the rail at derailment.

* FEM (Finite Element Method) analysis is a numerical analysis method for stress, temperature etc. It is a method to approximate the total behavior of an object of complex shape and characteristics by dividing that object into simple parts and adding up the calculation results of each part.

2.2 Performance Check

2.2.1 Stationary Load Test

We applied 200 kN to the contact point of the L-shaped guide using a stationary load tester to check the stress at individual parts of the guide. 200 kN is the load equivalent to the lateral load that is expected to act on the guides at derailment. The test results proved that no problems occurred because the stress at each part was less than proof stress of the material. Fig. 6 shows a picture of the stationary load test.
2.2.2 Stationary Tests Using a Bogie Testing Machine
In order to check bogie performance with L-shaped guides attached and the stress that is applied to the guides in running, we carried out stationary tests using a bogie testing machine that is able to simulate running in actual track conditions. Fig. 7 shows a picture of a stationary test.

The test results clarified that there was no increase of unsprung mass with L-shaped guides attached at speeds up to in excess of 360 km/h.

The results also proved that no problems occurred in terms of stress applied to the guides.

2.2.3 Running Tests Using Active Duty Car
Taking into account the test results using the bogie testing machine, we carried out high-speed running tests using a bogie of an E954 series Shinkansen high-speed test train with L-shaped guides attached.

The test results proved that no problem occurred in terms of running performance even when running at 365 km/h.

Fig. 8 shows the installation of an L-shaped guide to an E954 series car.

2.2.4 Verification Using a Train in Service
Based on the running tests result using an E954 series train, we carried out verification using actual trains in service, an E2 series Shinkansen train (Tokyo - Hachinohe) and an E3 series Shinkansen train (Sendai - Morioka, Morioka - Akita).

The verification results proved that there were no problems, as bogie performance was not affected either with or without L-shaped guides.

Since in verification using trains in service that there were no problems, we started installation of L-shaped guides to all Shinkansen train sets used for commercial service (except to the part of cars where life guards are installed) at general inspections or bogie inspections starting in January 2006. Installation was completed in the first half of fiscal 2008.

2.3 Durability Tests Using Active Duty Car Running at 320 km/h
In the running tests using an E954 train, the bogie with L-shaped guides showed no problems in terms of performance even at 365 km/h, and the L-shaped guides also had no problems in terms of strength.

We therefore started studies taking into account installation to E5 series Shinkansen trains that run in service at a maximum speed of 320 km/h. In durability tests, we attached the guides to all parts of the axle boxes (except the parts to which the life guard and the adhesion enhancer are attached) of an E954 series train and ran it at 320 km/h.

2.3.1 Development of an L-shaped Guide for Durability Tests Using an E954 Series Train
There are three types of bogies used for E954 trains. Since the shape of the axle box differs by bogie type, we developed L-shaped guides for each type in advance of the durability tests. Fig. 9–11 show the appearance of L-shaped guides for the individual bogies. We carried out strength tests of those guides by FEM analysis and by load tests. Fig. 12 shows an example of FEM analysis results for an L-shaped guide for E954 series cars.

The stress applied to each L-shaped guide was less than the stress applied to the guide for trains in service. We thus confirmed that there were no problems in terms of strength.
2.3.2 Durability Running Tests

We installed the developed L-shaped guide to trains from January to June 2009, running approx. 130,000 km. Periodical installation checks of attachment showed no abnormalities. The durability running tests on the E954 series train were completed in June 2009, and disassembly inspection of those is now underway. We are also planning to inspect conditions of the L-shaped guides.

We accomplished the following regarding the L-shaped guides.

(1) Stationary tests and running tests using active duty cars confirmed that the developed L-shaped guides have no problems in terms of strength and have no effect on bogie performance even at high-speed running.

(2) L-shaped guides were installed to all Shinkansen train sets as a countermeasure against derailment in earthquakes, supplementing the rail rollover prevention device wayside equipment.

(3) Durability running tests of the L-shaped guides attached to an E954 series train were conducted in consideration of installation to E5 series Shinkansen trains that run at a maximum speed 320 km/h in commercial service, and we found no abnormalities in items such as installation.

In the future, we will inspect conditions of the L-shaped guides in the disassembly inspection of the E954 series train used.

3 Conclusion

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