Unusual Behavior Detection and Non-Dismantling Diagnosis  
By Monitoring Bogie Conditions

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Summary
The current vehicle maintenance system of our company is “preventive maintenance.” This system assures that repair is not necessary until the next regular dismantling inspection. Therefore, while safety is sufficiently ensured, there is a possibility of over-repair.

The monitoring system of a bogie, which occupies a large part of the maintenance cost, is being developed for the purpose of optimizing the dismantling inspection period by shifting from “preventive maintenance” to “monitored maintenance” for cost reduction and adding a function of recognizing unusual points of a running vehicle and assuring safety to the present system.

For the first step, we have been developing detection technique for unusual behavior, such as hunting, unbalanced wheel load, and riding discomfort for which bogie deterioration becomes a cause, and derailment detection technique for safety enhancement.

We found that hunting, riding discomfort and derailment can be detected from body vibration by running-tests with a failed yaw-damper, practice examinations of derailment, and so on.

Regarding unbalanced wheel load, control technique of a dynamic wheel load is being developed, in addition to the conventional control of a static wheel load in a routine inspection. Further study will implement preparation of a maintenance standard for observation of vehicle behavior and development of technology to identify a deterioration cause.

Keyword
preventive maintenance, monitored maintenance, hunting, unbalanced wheel load, derailment detection
1 Introduction

A bogie is one of the most important parts for a train to maintain stable running. Therefore, bogies are disassembled periodically to check and repair in detail, as a rule of the EJR.

However, if a bogie can be monitored to understand its condition, reliability is expected to be increased in terms of travel safety. Namely, the following will become possible by realizing a bogie monitoring system with sufficient reliability.

1. Improvement of travel stability by understanding the bogie status continuously
2. Optimization of the bogie inspection and repair by carrying them out when signs of abnormality are observed.

The EJR is developing some bogie monitoring systems: the system which detects unusual agitation of bogies, the system which detects hunting and deterioration of parts like the yaw-damper, the system which detects wheel load change in a running vehicle, and the system which detects derailment.

Among these systems, the system which detects derailment, which is the most dangerous phenomenon for a bogie, is being further developed for prompt detection and damage suppression to minimum extent when derailment occurs.

2 Development of Derailment Detection Device

For the derailment detection system, it is important not only to detect derailment without fail but also to be cost-effective since the number of vehicles which the EJR has, for future derailment detection, is approximately 15,000. Therefore, the low-cost derailment detection device has been developed.

2.1 Goals for Cost Reduction

In order to reduce cost, not only of the device itself but also for its attachment and subsequent maintenance, the development was started with the following goals.

First, in terms of cost reduction of the device, (1) the diagnosis algorithm was to be simplified and (2) the amount of stored data was to be reduced to minimize the costs for CPU and memories.

Next, in consideration of the installation cost and the maintenance cost, (3) the vibration was to be detected not at a bogie but at a car body, (4) only vibration was to be detected so that other parameters, such as speed etc., would not be measured, and (5) the side of a car body, such as power distribution boxes, was a candidate for the place for the device.

(3) and (4) are for avoidance of the wiring between a bogie and a car body, and also for aiming at sensor reinforcement and reduction of maintenance. (5) is for making space for the device attachment not only in new cars but also in existing vehicles.

2.2 Judgment Method

Two simple judgment methods were devised for the algorithm simplification and the buffered data reduction.

2.2.1 Diagnosis 1

If the size of amplitude of the vibration of acceleration exceeds a threshold value and its occurrence frequency exceeds a certain level, the device makes a judgment of derailment.

(Fig. 1)
2.2.2 Diagnosis 2

The absolute value of the vibration acceleration is added up during a fixed period, and if the amount of the difference from the previous sum value exceeds a certain level, the device makes a judgment of derailment. (Fig. 2)
Regarding both methods, sampling time is 10ms and judgment period is one second. 6-20Hz vibrations are extracted by letting vibration data pass in a band path filter. This extraction is for removing momentary vibrations by track and travel conditions. This frequency band should be avoided and suppressed most in order to improve riding comfort when a vehicle is designed.

2.3 Vibration Measurement with Vehicle

2.3.1 Vibration in Usual Running Test
Since we use the algorithm in which derailment is detected from vibration, vibrations generated from usual running must be detected and the threshold value must be determined so that incorrect judgment would not be made.

In this development, the vibration meter was installed mainly on the assistant driver side of a driver’s cab, and vibration was measured with 7 types of cars and 10 types of tracks in 20,000 km of total test running.

2.3.2 Derailment Simulation Test
In order to simulate low-speed derailment, the vehicle for the simulation was pushed from the back toward a rail furnished with the derailment attachment (which causes a flange derailment by raising the wheel on a slope and guiding the flange across the rail), and the body vibration was measured during the period of derailment. (Fig. 3)

View from Upper side

Figure 3: Derailment Simulation Test

2.4 Test Results

2.4.1 Results of the Usual Running Test
The frequency distribution of the vibration data in the usual running test became close to the normal distribution, then, from the results of calculation of standard deviation, the 3 sigma value in which 99.7% of the data are contained became ±0.05[G].(Fig. 4) However, there were many vibration data points beyond this value. The maximum case of data that exceeded ±0.05[G] in one second was 72 out of 100.

Therefore, in Diagnosis 1, starting from 3 sigma, the judgment threshold value was increased with multiples of three and examined for all data of the running tests. Consequently, it turned out that the maximum number of the data which exceeded 9 sigma in one second was 17. Then, as a standard threshold value for the judgment by Diagnosis 1, acceleration of ±0.15 [G] or more and frequency of 20 times or more per one second were determined.(Fig. 5)

Regarding Diagnosis 2, from the measurement results in usual running, the maximum difference of the sum value from the value of each 1,2,3 seconds before was 6.46. Therefore, the difference of the sum value of 8 (non-dimensional number) or more was determined as a standard value for judgment.
2.5 Derailment Examination Result
The vibration acceleration extracted in the derailment test is shown in Fig. 6-1 and Fig. 6-2. Since there was a great difference between the outcome values in the usual running test and those in the derailment test, the threshold value for judgment of derailment detection was found to be effective.

![Figure 4: The Frequency Distribution of the Vibration Data in Usual Running (One Result of Tracks for Example)](image)

![Figure 5: Maximum Number of the Data Which Exceeded Threshold Value in One Second](image)
Figure 6-1: Derailment Examination Result

Figure 6-2: Judgment Value
3 Future Development and Subject

In addition to the monitoring system for derailment detection, the monitoring systems for detecting hunting of a bogie and wheel load change are being developed as well.

Regarding the hunting detection, some satisfactory results have been obtained using a failed yaw-damper. However, they are not effective enough to get useful information for maintenance.

With present sensing technology, state evaluation system for each constituent part of a bogie is expensive to develop. Therefore, we are now developing a more cost-effective system, that is, the monitoring system by which soundness of a bogie can be evaluated in terms of whole behavior of a bogie, such as hunting and wheel load change, instead of individual component behavior.