# Original and Innovative Onboard Systems to Address Rolling Stock Needs

*There is increasing demand for the basic requirements of safety, stable operation and comfort that vehicle is expected to provide, as well as for the reduction of costs required to maintain vehicle and tracks. To meet such demand, Kawasaki is developing various onboard systems and is moving forward to put them into practical application. These include an active suspension system that will improve passenger comfort, a Bogie Instability Detection System (BIDS) that will help ensure safe and stable operation and efficient bogie maintenance, and a track monitoring system that will help cut track maintenance costs.*

## Introduction

As a means to realize safe and secure mass transport with low cost, railways have been advancing in terms of the following aspects: actively introducing railway networks in emerging nations, and upgrading quick-deliverability, comfort and other convenience factors in nations with well-developed railway networks such as Western countries and Japan.

## 1 Background

Amid intensification of competition with airplanes and other means of transportation, railway companies have further improved convenience and accelerated initiatives to reduce lifecycle costs.

With growing demands of basic requirements for vehicle to provide safe running, ensuring stable operation and a more comfortable ride as well as requirements for railway companies to cut costs through more efficient vehicle and track maintenance, Kawasaki has supplied onboard systems meeting such demands.

## 2 New onboard systems

Kawasaki has developed onboard systems, which are in practical use, including the following: active suspension system that improves passenger comfort, Bogie Instability Detection System (BIDS) that helps ensure safe and stable operation and efficient bogie maintenance, and a track monitoring system that helps reduce track maintenance costs.

## 3 Active suspension system that improves passenger comfort

**(1) Overview**

With vehicle speeds increasing, ensuring passenger comfort has been challenging in recent years, and as one of the technologies to cope with this challenge, the vibration control technology to control vehicle vibration has become vital. Its overview is shown below.

(i) System configuration of vehicle

Causes of vehicle vibration include transmission of vibration of a bogie excited by track irregularity to the vehicle's body and direct excitation of the vehicle's body due to aerodynamic force from traveling at high speeds. Attributed to faster vehicle, difficulty in controlling vibrations from two different sources only through the tuning of springs or dampers on a vehicle has arisen.

(ii) System configuration of active suspension system

To address the problem mentioned above, an active suspension system has been developed to detect vehicle vibration using sensors and to generate some force to cancel out vehicle vibration using an actuator mounted between the bogie and vehicle body, and has been adopted mainly in Shinkansen (bullet train) and other high-speed vehicle (Fig. 1).

**(2) Initiatives carried out at Kawasaki**

The development status in Kawasaki is described below.

(i) Development and performance evaluation of active suspension system

Taking into account the recent growing demand for

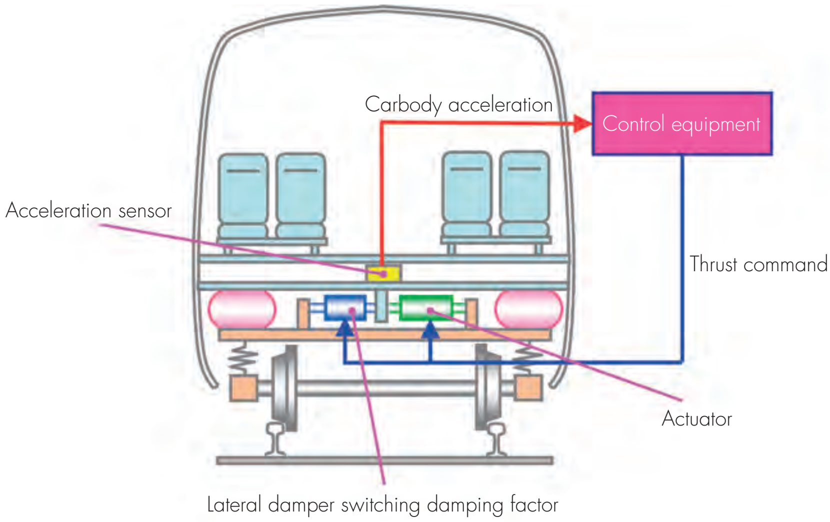



Fig. 1 System configuration of active suspension system

reduction in air consumption, in particular, and improvement in actuator response, we have developed an active suspension system using electric actuators, replacing conventional pneumatic actuators that are primarily used. The results of performance tests carried out so far using bench test equipment or test vehicle have proved its high vibration control performance (Fig. 2).

(ii) Development of new actuator

Recently, from the viewpoint of better passenger service, there has been an increasing demand for active suspension systems not only for Shinkansen and other high-speed vehicle, but also for limited express trains on conventional lines and other mid-speed vehicle. Further downsizing of an actuator is required for mid-speed vehicle, and to meet such requirements, Kawasaki has newly developed a small, lightweight actuator.

Use of a highly accurate ball screw in the drive unit enables efficient power transmission, and as a result, in addition to downsizing and weight reduction, adequate high output performance has been achieved with an excellent energy-saving feature (Fig. 3).

Mounted on GCT (gauge change train) new test vehicle, which can run on tracks of two different rail gauges, the system has proven it has good vibration control performance in running tests on both Shinkansen and conventional railway tracks.

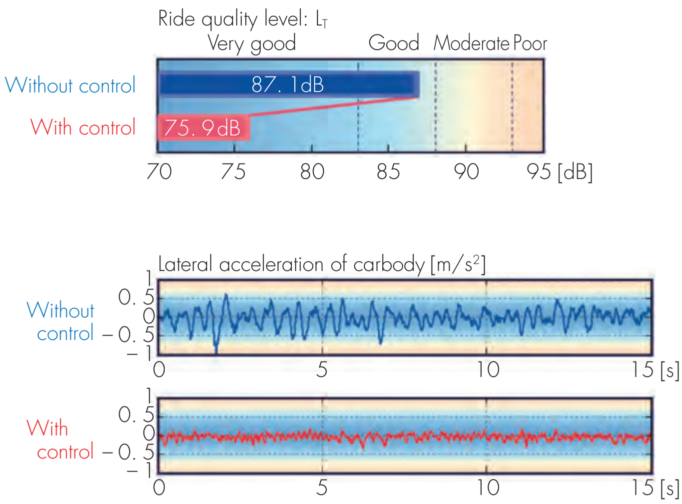



Fig. 2 Running test results

| | For high-speed vehicle | For mid-speed vehicle |
|---|---|---|
| Type | Ball screw drive | |
| Weight [kg] | 40 | 32 |
| Installation length [mm] | 470 | 462 |
| Thrust [N] | Max. 8,000 | Max. 6,000 |
| Application target | GCT new test vehicle | – |

Fig. 3 New actuator for active suspension system

## 4 Bogie Instability Detection System, BIDS, that realizes safe and stable running

### (1) Overview

Bogies are one of the most important components composing vehicle, and are designed with various considerations to achieve safe and stable running. However, the following matters cannot be avoided just by considering them in the design stage, and require other measures.

- Degradation of supporting component, wheel abrasion or other relevant factors may cause an unstable phenomenon called hunting, and leaving such a phenomenon unattended poses a higher risk of derailment.
- Trouble with axle bearing, gear unit, coupling joint or other components in drive transmission system hampers vehicle's stable operation.

Aiming at avoiding both above cases, Kawasaki has developed BIDS (Bogie Instability Detection System), a system to monitor status of a bogie by sensing vibrations and temperatures, and has expanded its use mainly in overseas high-speed vehicle.

### (2) System configuration

As shown in Fig. 4, BIDS measures lateral vibration using the acceleration sensor mounted on a bogie frame, and detects indication of hunting at the monitoring unit in accordance with level and continuity of vibration. Detection results are immediately notified to the driver so as to safely decelerate the vehicle. Drive transmission systems are monitored mainly by the temperature switches, and abnormal rises in temperature are directly notified to the driver's cab.

### (3) Characteristics

(i) Highly sensitive of acceleration sensor hunting detection performance

Extraction of the hunting frequency component determined based on bogie design specifications and running speed allows detection of hunting in the early stages. Additionally, the system can adapt to the higher speed of vehicle.

(ii) Highly reliable in poor environments

Even in such severe environments as vibration, shock, intensive surge and noise, the system maintains its performance without any trouble, and is free from periodical calibration and maintenance.

### (4) Applications

(i) BIDS for high-speed vehicle

We have started delivery to Taiwan High Speed Rail Corporation and China South Locomotive and Rolling Stock Industry Group Corporation. The cumulative shipments have exceeded 5,100 sets. Also, to supply the system for unified standard vehicle, which is under development by China Railway Rolling Stock Corporation, a new system has been newly developed to adapt to world-standard vehicle network of MVB (Multifunction Vehicle Bus) and Ethernet

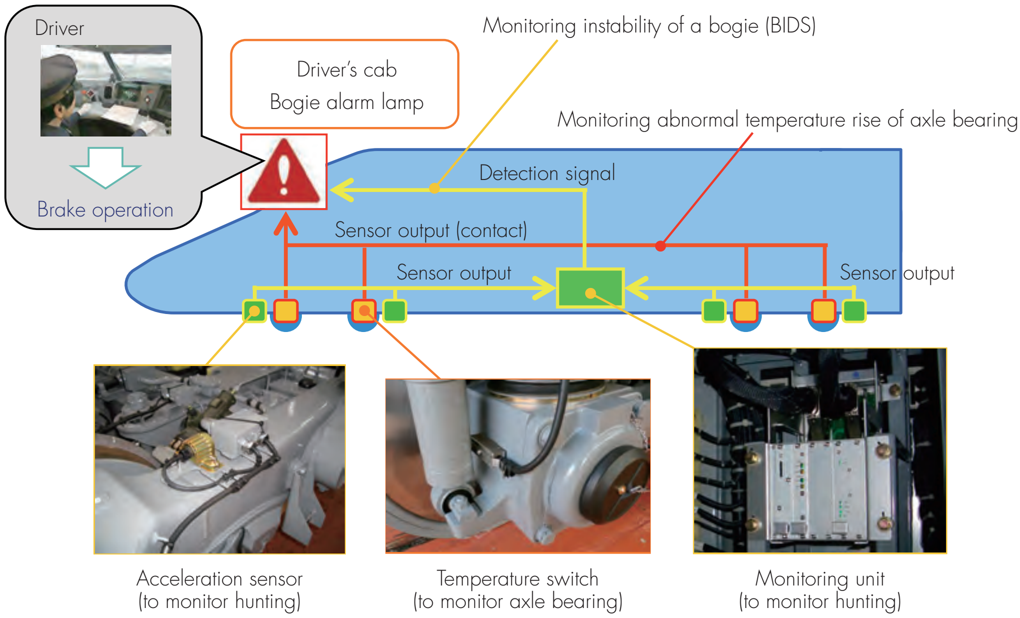



Fig. 4 System configuration of BIDS

that is expected to dominate in the future, and as a result, substantial functional improvements have been achieved, leaving the body dimensions and shape as they stand.

(ii) BIDS for efWING

A new monitoring system has been developed to be mounted on the next-generation bogie efWING (Fig. 5 (a)) that has adopted CFRP (carbon-fiber-reinforced polymer) in the main structure of the bogie frame. Unlike the conventional type, this system is characterized by the fact that the monitoring unit is directly mounted onto the bogie. At present, continuous evaluation is being performed on durability and reliability using a system mounted onto actual vehicle.

① Bogie-mounted monitoring unit (Fig. 5 (b))

It was verified that, even in an extremely severe environment on a bogie, the unit works properly and maintains vibration/shock Category 2, IP66 for dust/water resistance, and the other performances shown in Table 1.

② Health monitoring sensor for CFRP leaf spring

Employing the in-house-developed sensing method using the conductivity of CFRP, the system allows continuous monitoring of not only vibration and temperature but also the internal state of the CFRP leaf spring.

③ Remote monitoring and state diagnosis

Transmitting the bogie's behavior data during running as needed via a wireless communication line to our data center, the system allows abnormalities in the bogie's behavior to be analyzed and diagnosed.

**(5) Higher level of maintenance efficiency led by condition monitoring**

Kawasaki has built and operated the system with more monitoring items extended from conventional BIDSs, and has launched continuous collection of the bogie's behavior data. Along with sophistication of diagnostic technology based on the collected data, we are building a system for monitoring and diagnosing conditions (Fig. 6) at the bogie's component level through the active use of IoT (Internet of Things) technology, and are striving to achieve both safety and stable operation and maintaining bogies more efficiently.

(a) efWING

(b) Monitoring unit

Fig. 5 efWING and bogie-mounted monitoring unit

Table 1 Main specifications of bogie-mounted monitoring unit

| Item | Specifications |
|---|---|
| Ambient temperature | −25°C to 70°C |
| General environment | IEC60571<br>(humidity and temperature, insulation resistance, etc.) |
| Electromagnetic compatibility | IEC62236-3-2<br>(surge on vehicle, noise, etc.) |
| Vibration/shock test | IEC61373 Category 2<br>(bogie-mounted equipment) |
| Dust resistance, water resistance | IP66 equivalent<br>(water-resistant type, strong direct jet stream) |
| Number of measuring points | 13 points |
| External interface | Power supply, running speed information line,<br>LTE/3G transmission line |

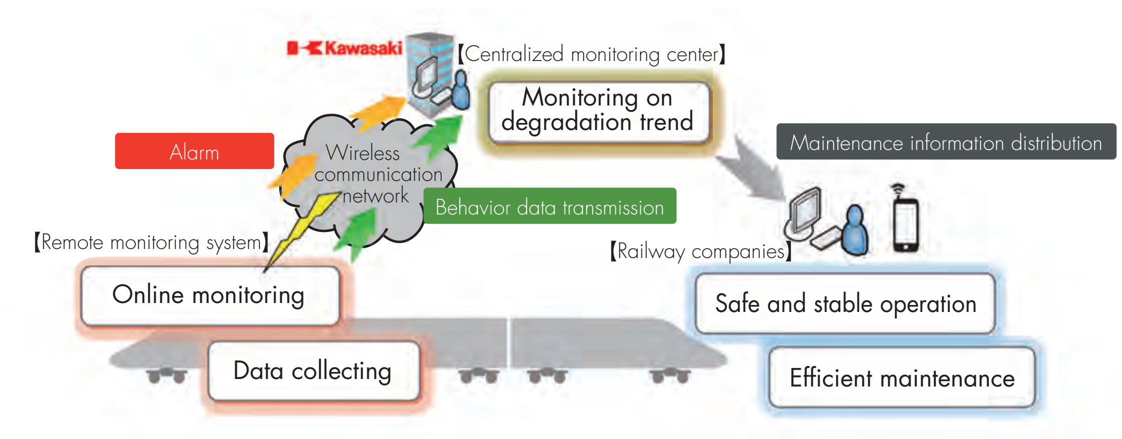



Fig. 6 Remote monitoring and diagnostic system

## 5 Track monitoring system that guarantees safety from tracks

**(1) Overview**

Track facility maintenance depends primarily on visual walking inspections, and for this reason, saving energy and automating track maintenance and inspection work has been an important issue for railway companies.

Kawasaki has developed a track monitoring system for East Japan Railway Company (JR-East) to meet the abovementioned demands. Following are the characteristics of this system:

① Recording running feature

Ten cameras mounted on the onboard equipment shown in the frontispiece photo enable the continuous recording of track images during traveling.

② Automatic detection feature

Using ground equipment, the system allows automatic detection of abnormalities in the rail fastener and fish plate through image processing.

③ Compact housing size

In terms of size, the onboard equipment can be installed under a floor of vehicle and be mounted onto commercial vehicle. Using such an advantage, the system allows the latest track images to be obtained with high frequency during routine commercial driving.

**(2) System configuration**

Figure 7 shows the system configuration of the onboard equipment, and the information below describes features of the configuration.

・The onboard equipment consists of the following items:

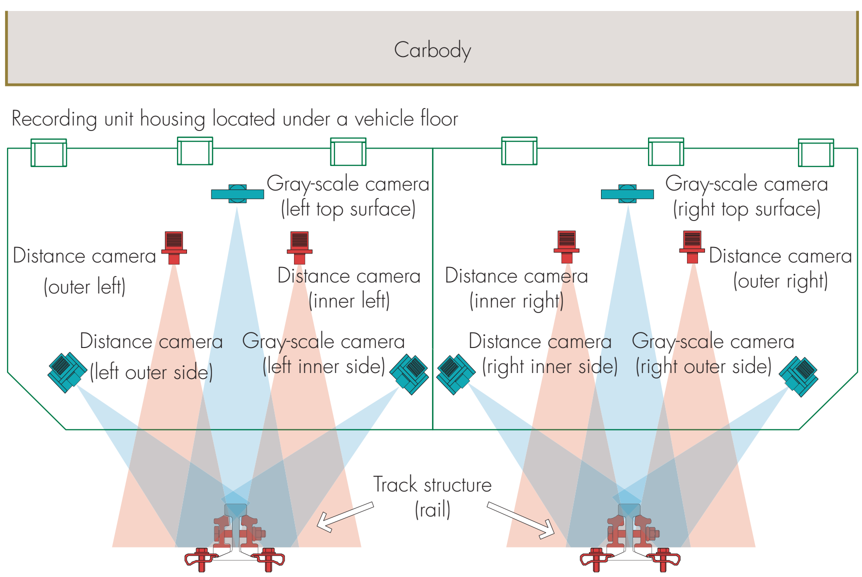
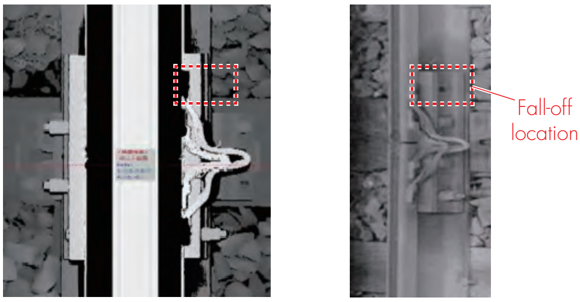



Fig. 7 System configuration of onboard equipment




(a) Distance camera (b) Gray-scale camera (side view)

Fig. 8 Detection result of fish bolt defect

six gray-scale cameras that capture gray-scale images of track surfaces for visual monitoring, four distance cameras that capture three-dimensional form for automatic detection of falling-off of rail fastener and fish bolt, a controller that controls the abovementioned cameras, and a data recording unit.

- Synchronizing with the pulse output by the vehicle mounted velocity sensor at a constant distance, the respective cameras carry out shooting.
- Captured track images are stored in the data recording unit and periodically extracted.
- Using the ground equipment in an office, image processing and detection processing are done offline.

Automatically detectable items include falling off of diverse kinds of rail fasteners, fish plates and fish bolts. Figure 8 shows the location where fall-off was automatically detected through detection processing.

**(3) Applications**

Since fiscal 2013, the system has been mounted on commercial vehicle on the Tokyo metropolitan area route run by JR-East, and the one-year trial operation was performed.

Mass production started in fiscal 2014, and the said system has also been applied in the Chuo Line and the Yamanote Line, and started its service in fiscal 2015. Going forward, we plan to mount the system for the other railway routes in sequence.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## Conclusion

We assume that the onboard systems introduced this time can contribute to a safer and more comfortable ride and stable rolling stock operation as well as reducing maintenance costs.

It was essential to have guidance and cooperation from JR-East, Kumamoto Electric Railway Co., Ltd. and other railway operators for developing the respective onboard systems. We deeply acknowledge all relevant parties with our sincere gratitude.