Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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Recent Research and Development by RTRI

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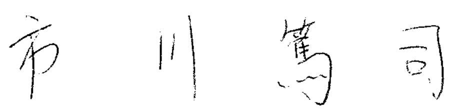
The Railway Technical Research Institute (RTRI) has four priority objectives for research and development – “improvement of safety,” “harmony with the environment,” “cost reduction” and “improvement of convenience.” To effectively pursue these objectives, RTRI has adopted three research categories - “basic research for railways,” “development of practical technologies” and “research and development for the future of railways.” In this context, RTRI has adopted important subjects to be addressed on a preferential basis. These subjects deal with the changes in recent years in the environment surrounding railways. For this purpose, researchers are promoting research for 250 to 300 themes every year, of which the most emphatically being promoted in recent years are research and development to a) upgrade simulation technologies, b) address natural disasters that are becoming increasingly extensive in scale and c) develop better energy saving technologies. These are summarized below.

· Enhancement of simulation technologies
To develop new technologies, railways have historically attached importance to various tests and measurements in laboratories, in the field and on test tracks. However, the remarkable progress of computer technologies in recent years has resulted in a number of simulation technologies to supplement these tests and measurements. As a source of innovation for railway technologies, RTRI is making efforts to upgrade simulation technologies by developing a comprehensive simulator to reproduce various behaviors in a wide variety of railway environments and conditions.

· Research and development to mitigate natural disasters
It is apparent that natural disasters, such as rainfalls, strong winds or earthquakes that hit Japan are steadily becoming more hostile year after year and are leaving destructive scars behind. As an example, the number of places where rainfall exceeds 80 mm per hour or 400 mm per day has approximately doubled in 30 years. Thus, while RTRI was promoting various research and development activities based on a concept to “prevent damage,” the emphasis has now been redirected slightly for research and development to “minimize damage,” given the natural disasters at unprecedentedly gigantic scales in recent years.

· Research and development of energy saving technologies
The Tohoku Region Pacific Coast Earthquake (in 2011) destroyed a nuclear power station (in Fukushima Prefecture). This accident thrust the issue of saving energy before Japan as a subject of utmost importance. Whereas the railway industry has an unrivaled high efficiency of energy consumption, railways are now required to further improve the efficiency of energy utilization. Under the circumstances, RTRI will promote the following activities in the near future. Namely, RTRI will:
· Propose technologies to enable a 20% increase in the efficiency of energy utilization by 2030.
· Establish a technique to quantitatively assess the volume of energy consumed in different fields of the railway system.
· Collect, analyze and transmit the information on energy saving technologies.



RTRI Stand at InnoTrans2012

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RTRI exhibited its research activity at InnoTrans2012 held in Berlin on September 18 to 21, 2012. It was the third opportunity for RTRI since it started to display its research products at the exhibition in 2008. Whereas, in 2008 and 2010 RTRI advertised its original technologies that were ready to apply to practical use, in 2012 RTRI displayed its technical potential in fields covering almost all technologies applied to railway industries.

The RTRI stand made up part of the Japan Pavilion organized by Japan Overseas Rolling Stock Association (JORSA). The pavilion occupied a 680 m^2 hall with booths consisting of 17 Japanese companies. The atmosphere created by the red facade of the stand structure and the demonstration of a Japanese tea ceremony performed by Kimono-wearing women provided a great attraction for visitors to the stands in the Japan Pavilion. See Figs. 1 and 2.

Thanks to the creative atmosphere of the Japan Pavilion, the RTRI stand received more than several hundred visitors during the four-day exhibition period. Figure 3 shows the RTRI stand. Because the rear wall of the stand displayed two types of prototype vehicles designed by RTRI, a number of visitors asked RTRI attendants questions on vehicle technologies. Large pictures of Hi-tram, an energy recycling car, and fuel-cell rolling stock succeeded in enhancing visitors' curiosity about the RTRI stand. The visitors, who were first interested in vehicle technologies, sometimes diverted their interest to other fields also developed by RTRI when they found that RTRI covers a variety of research fields. RTRI's display also worked to satisfy such visitors' intellectual appetite. RTRI was able to provide the visitors with information on a wide range of research topics conducted by the 12 research divisions of RTRI having more than 400 researchers in total.

RTRI keeps working to create new technologies and find solutions useful for railway systems. RTRI is also looking for new research topics at a potential high enough to stimulate railway technology researchers. It is RTRI's pleasure to discuss railway technologies with you at the next opportunity.

Fig. 1 Japan Pavilion at InnoTrans2012

Fig. 2 Japanese tea ceremony

Fig. 3 RTRI-stand at InnoTrans2012

SNCF-RTRI Collaborative Research Seminar 2012

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The Railway Technical Research Institute (RTRI) hosted the SNCF-RTRI Collaborative Research Seminar 2012 on September 26 to 28, 2012. It was attended by seven delegates from SNCF led by Mr. Emmanuel MANIER, Head of Engineering department, French National Railways. Research results were presented to the participants on the four fifth-term research themes "Inspection and Predictive Maintenance Strategies for OCS on High-Speed Lines," "Standing Comfort," "Wireless Sensor Networks" and "Research and Development Management." These themes have been promoted for two years since 2010.

After the Seminar, RTRI and SNCF came to an understanding that the two parties would continue with joint research collaboration and adopted the five sixth-term research themes of "Inspection and Predictive Maintenance Strategies for OCS," "Standing Comfort," "Saving Energy System for Power Supply," "Simulation Models of Ballasted Track" and "Research and Development Management." The parties also agreed to hold the next Seminar in France in 2014.


Fig. 1 Participants from SNCF and RTRI

Fig. 2 The representatives of SNCF and RTRI signing the agreement


Fig. 3 A scene of discussions on research themes

Fig. 4 A speaker making a presentation on the fifth-term research results

Development of Automatic Irregularity-Correcting Sleepers

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Background

In ballasted track, when sleepers are hanging from the rails without contacting the ballast under no train loads they are called hanging (or suspended) sleepers. When a train passes on the track under these conditions, the hanging sleepers contact the ballast below and generate impact loads that can break ballast and/or cause mud-pumping. This causes track conditions to quickly deteriorate. Hanging sleepers tend to occur mostly in the vicinity of rail joints and the boundary between ballasted and ballastless track and at other places where the settlement of ballasted track is discontinuous (Fig. 1).

RTRI has been developing different versions of automatic irregularity-correcting sleepers (AICS) that will automatically compensate for discontinuous settlement of ballast tracks and minimize the occurrence of hanging sleepers. This paper introduces one version; a low-cost short-sleeper type (hereinafter referred to as "AICS-SS"), which will soon be commercialized.

Summary of AICS-SS

An AICS-SS is a short sleeper version to be fixed on the rail bottom with strong magnets between existing sleepers. In effect, it creates an extra (short) sleeper as shown in Figs. 2 and 3. Each AICS-SS has a built-in automatic subsidence compensating (ASC) device composed of a set of nested cases. See Fig. 4. The inner case is filled with granular particles, about 2 mm in diameter. The top of the inner case contacts the bottom of the rail via an insulating plate and the bottom of the outer case contacts the ballast via a base plate. When the surrounding ballast sinks together with the outer case, a gap is formed between the inner and outer cases allowing the granular particles in the inner case to drop through an outlet bored in the bottom of the inner case. These particles fill the gap between the two cases to subsequently increase the effective height of the device. As a result, the AICS-SS maintains the rail level unchanged and prevents the state of hanging from occurring even as local ballast settlement progresses.

Figure 5 illustrates changes in the amplitude of rail displacement in repeated loading tests on rail joints of a life-size track model in a laboratory. Deteriorated ballast with a high sediment mixture ratio was used to simulate a local line. During load application, water was sprayed to simulate a heavy rainfall. In the case where AICS-SS were not used, the ballast lost strength after the water spray and became muddy. This caused hanging sleepers to occur and the support rigidity was sharply decreased as a result. In the case where AICS-SS were used on the other hand, decreases in the support rigidity due to watering were nominal, while the amplitudes of rail displacement remained at 2 to 3 mm, even when the axle load was increased to 205 kN. This demonstrates that AICS-SS have the potential to prevent hanging sleepers even under high axle load conditions on deteriorated ballast tracks.

RTRI is now checking the practical validity of AICS-SS on a trial basis on an actual track while aiming at commercialization of the devices at the end of 2013.

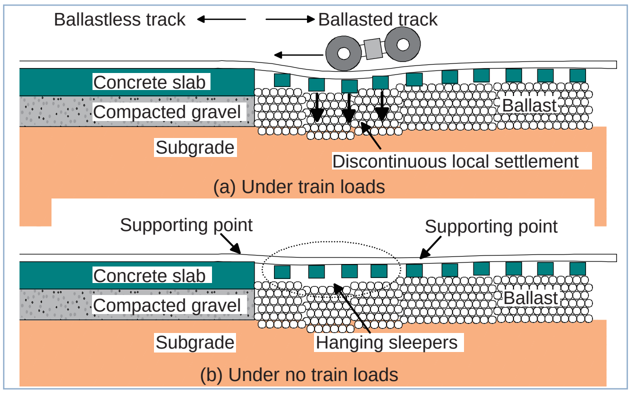

Fig. 1 A concept of the state of hanging sleepers in the transition zone

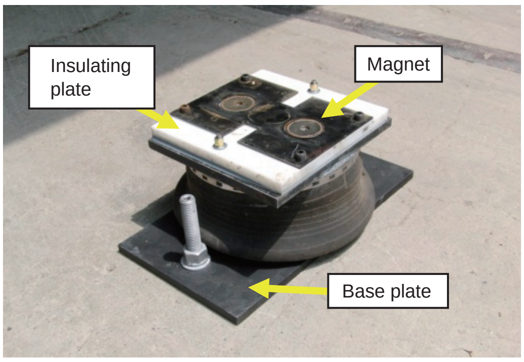

Fig. 2 A prototype of AICS-SS

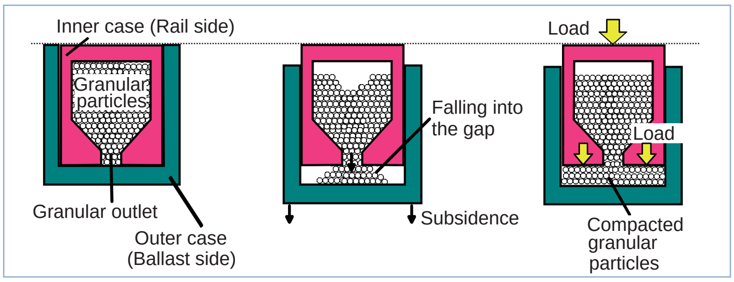

Fig. 4 Principle of the automatic subsidence compensating device

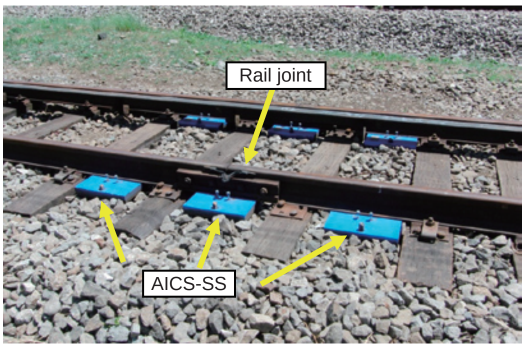

Fig. 3 AICS-SS installed on a track

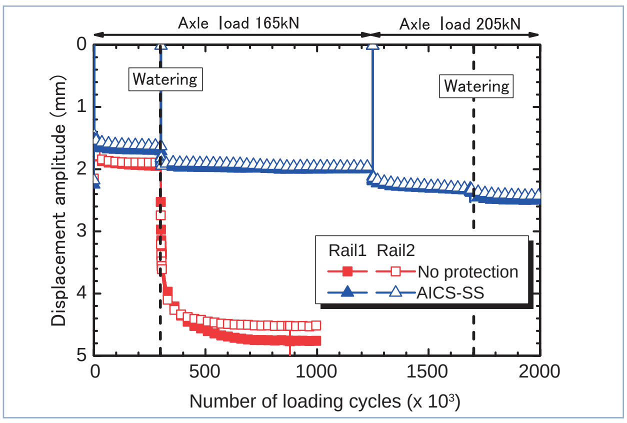

Fig. 5 Amplitudes of displacement of the left- and right-side rails

A New Vertical Vibration Control System
– Development and Commercialization –

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In some track sections where current maintenance criteria are not so high, cars can exhibit rigid body vibration (bouncing/pitching vibration) in the vertical direction when they pass rail joints or run on tracks with large irregularities. As this motion is often detrimental to ride comfort, it is essential to decrease vertical car-body vibration in order to guarantee satisfactory ride comfort for passengers on board the cars running in such sections.

Active or semi-active suspension systems are effective in reducing car vibrations, but such suspension systems have not been employed for trains in service to reduce vibration in the vertical direction. However, RTRI has developed a secondary suspension vibration control system using vertical vertical hydraulic dampers and actually applied it to sightseeing limited express trains on narrow-gauge lines.

Figure 1 illustrates the vertical vibration control system of the secondary suspension. The car is equipped with four sets of variable damping vertical dampers arranged in parallel to the secondary suspension. Based on the information from the acceleration sensors installed at four places on the car-body, the control unit calculates the force to be generated by dampers to decrease vertical car-body vibration acceleration and transmits the information as a command current to the dampers.

Figure 2 shows a variable damping vertical damper. The installation length of the damper is the same as that of a conventional vertical damper to ensure easy replacement. Without requiring large-scale remodeling on cars, therefore, it is possible to introduce the new system by simply installing a control unit, acceleration sensors and newly developed dampers to replace the conventional ones.

Figure 3 represents the algorithm to control dampers. It applies the sky-hook control law separately to each of the vertical bounce, pitch and roll components, with the sky-hook gains adjusted based on running tests.

Figure 4 shows a photo of the control unit, equipped with functions to control the damping force of each damper and to monitor failures/abnormalities of dampers, sensors and the system as a whole.

Figure 5 graphically represents the car-body vertical vibration acceleration Power Spectral Density (PSD) in the sections where vertical rigid body mode vibration is particularly conspicuous, as measured in the running tests on a local line. A peak of acceleration PSD due to rigid body mode vibration is observed at approximately 1.7 Hz. When dampers were controlled, vibration in the frequency band of 1 to 2 Hz decreased, with the PSD peak at 1.7 Hz decreased by 80%.

As a result, the L_T value, a ride comfort evaluation index generally used in Japan, dropped approximately by 4 dB. For reference, smaller L_T values indicate better ride comfort. It is generally accepted that passengers feel a difference in ride comfort, when the L_T value changes by 3 to 5 dB.

The developed system has been incorporated into JR Kyushu's sightseeing limited express trains in revenue service, " Ibusuki no Tamatebako" (seen in Fig.6) and "Hayato no kaze".

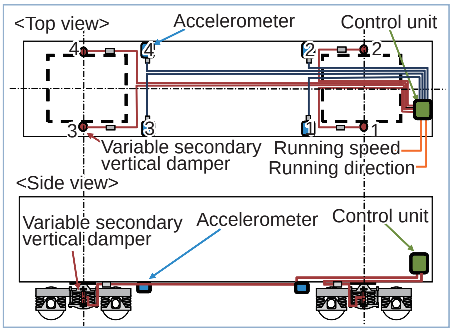

Fig. 1 Composition of the vertical vibration control system

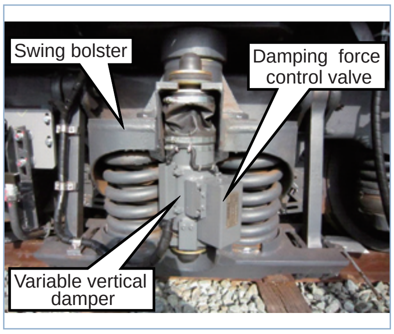

Fig. 2 A variable damping vertical damper

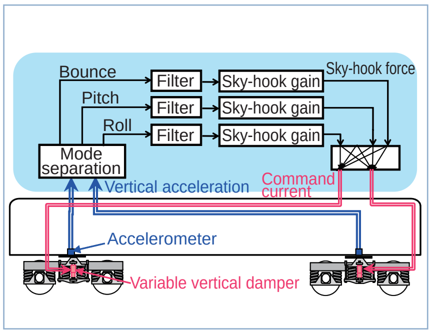

Fig. 3 Control algorithm

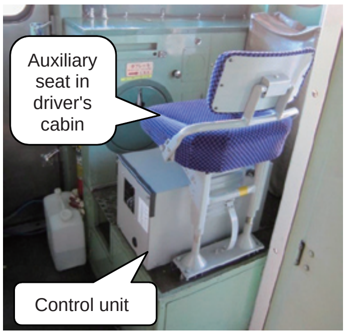

Fig. 4 A control unit

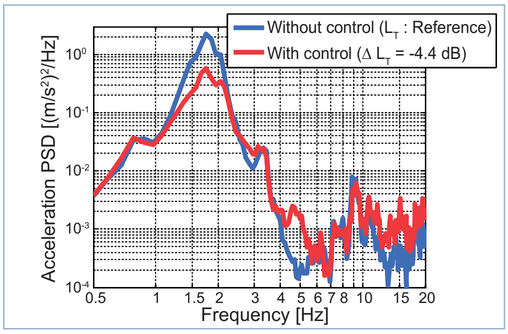

Fig. 5 Car-body vertical vibration acceleration PSD at 75 km/h, measured immediately above the bogie

Fig. 6 Sightseeing limited express train "Ibusuki no Tamatebako" installed with the new system

Reduction of Car Body Elastic Vibration Using High-Damping Elastic Supports for Under-Floor Equipment

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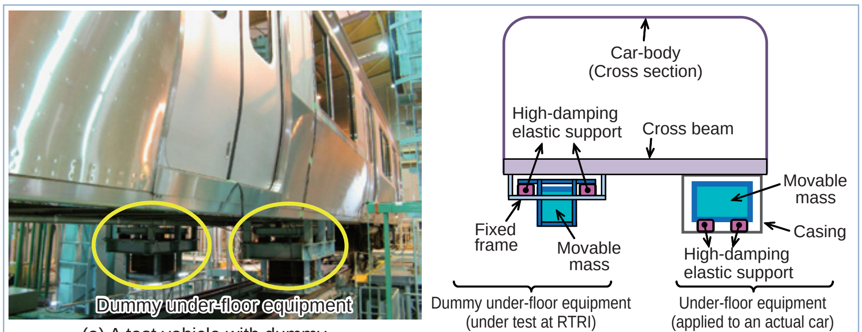
Reduction of car body elastic vibration has become more important than ever in order to maintain and improve the present level of ride comfort, particularly given today's higher operating speeds and lighter weight railway vehicles. The Railway Technical Research Institute (RTRI) has been studying methods to reduce car body elastic vibration and has now developed a high-damping elastic support for under-floor equipment that reduces the elastic vibration of the car body. By supporting under-floor equipment elastically with high-damping members, not only is the car body elastic vibration reduced but also propagation of the vibration generated by the under-floor equipment is suppressed. It is quite simple to apply this technique to rail cars, as it requires only nominal changes to the supports for existing under-floor equipment while adding only a small amount of mass to the car body.

This high-damping elastic support for equipment is designed to have a similar effect as passengers by reducing car body elastic vibration. It is normally thought that passengers are equivalent to an increase in the mass of car body and work to reduce its natural frequency. In contrast to this generally accepted view, the author and co-researchers have clarified that passengers (1) do not change the car body natural frequency significantly, which means that passengers exert an effect different from that of increased car body mass and (2) substantially reduce car body elastic vibration.

As already known, the human body has two specific vibration characteristics; a comparatively low natural frequency, 5 to 6 Hz, and high damping performance. In the course of this study, the researchers also clarified that these vibration characteristics work to reduce car body elastic vibration. They also demonstrated that car body vibration can be reduced in a wide frequency range without cumbersome work to adjust for natural frequency or damping ratio required for normal dynamic vibration absorbers when passengers are aboard. These findings suggest that a new effective damping device can be developed to suppress car body vibration, if these human characteristics can be simulated appropriately.

Thus, using materials featuring higher damping than that of the car body, RTRI manufactured prototype high-damping elastic supports to set the natural frequency of the under-floor equipment suspension system lower than that of car body. In order to test the prototypes, RTRI installed two sets of dummy under-floor equipment which are suspended using the high-damping elastic supports (one having an electro-dynamic exciter to simulate vibration generation of the under-floor equipment, and the other being just deadweight) on a test car equivalent to those used for commuter transport, as shown in Fig. 1. The hanging support structures are similar to the hydraulic mounts used for automobiles and construction machines. The high-damping elastic supports were subjected to excitation tests at RTRI's rolling stock testing plant. The tests confirmed the validity of the high-damping elastic support. As shown in Fig.2, the new supports reduce multiple modes of car body elastic vibration simultaneously and insulate the vibration from equipment. The vibration of the under-floor equipment remains substantially unchanged or rather reduced (see Fig.3).

The high-damping elastic support for equipment can be implemented on various cars as it features a lightweight structure, there is no need for specific maintenance and it is a convenient method to reduce car body elastic vibration.



(a) A test vehicle with dummy under-floor equipment
(b) Application of the high-damping elastic support

Fig. 1 Test vehicle under excitation test at RTRI's rolling stock testing plant and a schematic illustration of the application of high-damping elastic supports

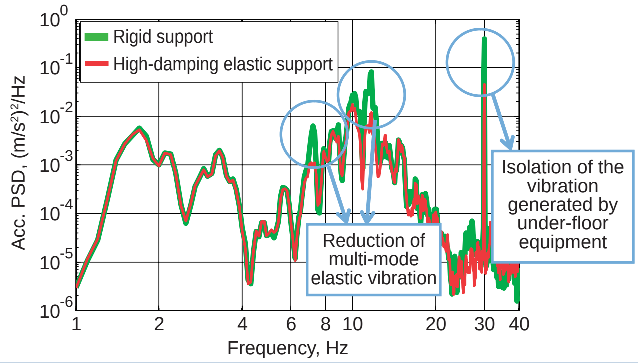


Fig. 2 Acceleration PSD on the car-body floor (measured under the central window)

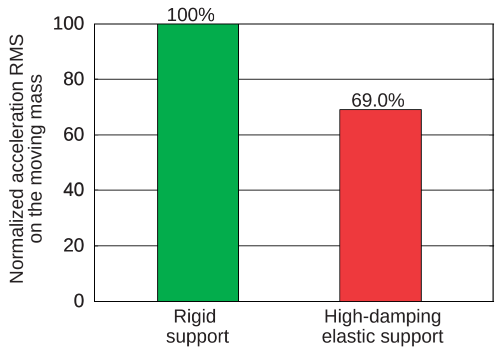


Fig. 3 Acceleration RMS of the mass of a dummy equipment (normalized with the case of rigid support taken as 100%)

Detection of Pantograph Failures Using Sensors Fixed to the Catenary System

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A serious failure of a pantograph not only can damage contact wires at the point where the pantograph fails but can also inflict widespread damage on the catenary system network. Pantographs are subject to regular inspection at rolling stock depots, but there are some defects that are difficult to detect by the visual checks. In addition, the visual check at the depots cannot directly help to quickly detect pantograph failures in operation. For these reasons, development of a reasonable abnormality-detecting technique is needed in order to assess pantograph abnormalities in quantitative terms at high frequencies. Hence we developed a technique to monitor pantographs passing a particular section where sensors are fixed to the contact wire and their components, thereby detecting pantographs operating under abnormal conditions without delay. This particular study focused on monitoring two types of pantograph defects, i.e., (1) the uneven (step-shaped) wear of pantograph contact strips and (2) the abnormal aerodynamic upward force working on the pantograph.

(1) Detection of uneven wear on contact strips

To detect contact strips having uneven wear, vertical/lateral vibration sensors fixed on the contact wire are used to observe the abnormal vibration caused by the uneven wear. See Fig. 1 for a schematic drawing of the system used for this purpose. The schematic shows one potentiometer and five vertical /lateral accelerometers placed as shown. However, the type and the number of sensors depend on the train speed or the type of catenary system in the section where this system is installed.

(2) Detection of abnormal aerodynamic upward force

The system measures (1) the dropper tensile/compressive force in the vertical direction and (2) vertical gradient of the contact wire in the monitoring section. Then, it calculates the average contact force between contact wire and pantograph, which equals the sum of the static upward force and aerodynamic upward force. In case the resultant value exceeds the allowable limit, the system judges that the aerodynamic upward force is abnormal. See Fig. 2 (a) for the disposition of the sensors used in this study.

To verify the abnormal pantograph detecting technique introduced above, we implemented running tests in the premises of the Railway Technical Research Institute and confirmed the following:

(1) The pantograph wear detecting system is capable of detecting the uneven wear of pantograph contact strips with high precision in a speed range up to 120 km/h.

(2) The abnormal aerodynamic upward force detecting system can observe the average contact force at sufficiently high precision. See Fig. 2 (b).

It should be noted, however, that in this test to check the abnormal aerodynamic upward force detecting system, we changed the pantograph static upward force between +30 and -30 N, instead of changing the aerodynamic upward force itself.

This technique detects pantograph abnormalities and meets the purpose of this study, thereby providing an effective contribution to the prevention of contact line failures.

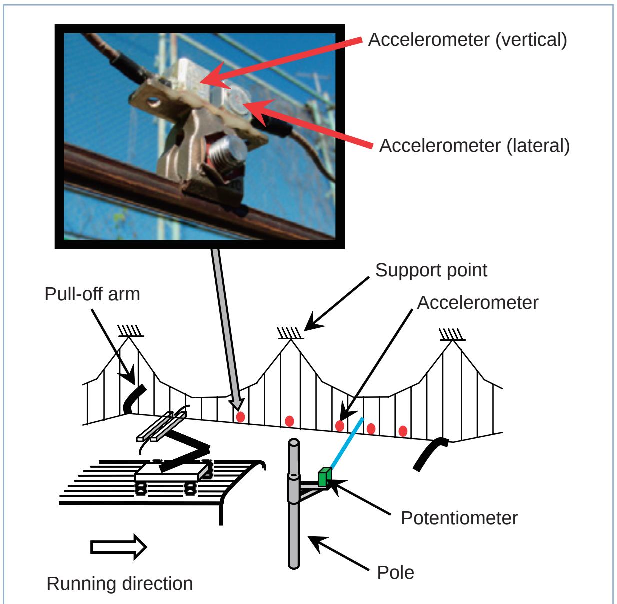

Fig. 1 Disposition of sensors to detect uneven wear on contact strips

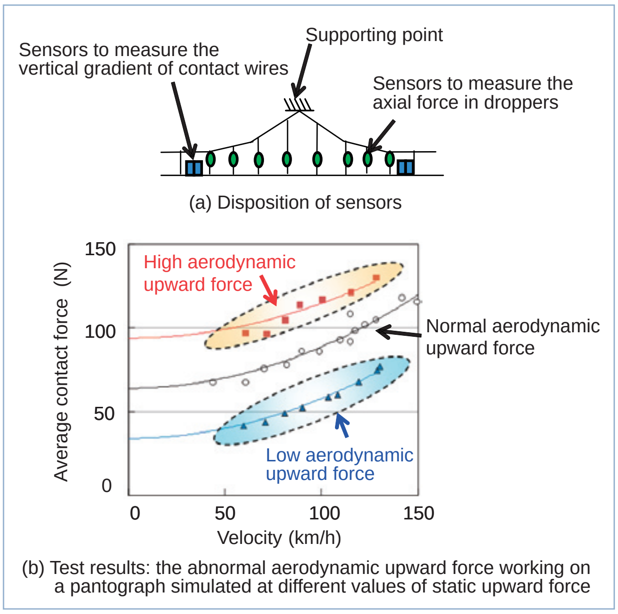

Fig. 2 Detection of abnormal aerodynamic upward force