Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

Preface

Koichi GOTO
Director, International Affairs Division

I like reading novels. I often read those originally written in foreign languages and translated into Japanese. Thanks to excellent translators, however, I can enjoy the worlds created in foreign novels and to understand cultures and societies in their background that are different from those in Japan. I appreciate the value of the diversity of cultures and sympathize with these different cultures fairly well though not completely, presumably because there is commonness in the styles of art and thinking of people among different countries. Although I have been enjoying cartoons and animations as well since my childhood, I never realized that they are also welcome in other countries. But now I know that there are long-loved comics in other countries, such as Bande Dessinée in the French-speaking regions and comics in America that Japanese people are also enjoying. There is universality in the basis of societies and personality of artists around the world. This holds true with railways as well. I often take trains in foreign countries, when I feel how pleasant it is to see not only sceneries through train windows but also the trains themselves, which are specific not to anywhere but certainly to the country or region where I am traveling. I wish for and believe such diversity be maintained for ever. There is also commonality behind this diversity. Not only are the physical phenomena in running trains the same but also tracks, rolling stock, signals and other matters related to railway technologies are very similar. Mutual introduction of superb technologies expands the scope of commonality. In fact, efforts to expand standardization aimed at the development and efficiency improvement of railways has become increasingly active in recent years.

The Railway Technical Research Institute (RTRI) is now positively promoting joint research and exchanging human resources with overseas organizations, while releasing the outcomes from its research activities at a number of international workshops/conferences, in various journals and through the publication of News Letters and Quarterly Reports (QRs). RTRI is also participating in the international standardization activities for railway technologies as a secretariat organization in Japan. For the World Congress on Railway Research scheduled in November 2013 (WCRR 2013), RTRI is deploying various activities as a member of the Organizing Committee to achieve a successful Congress.

I wish to contribute to the development of railway technologies further to make a basis of high-level railway services rooted in various regions in the world through cooperation, exchange and transmission of information with the research organizations in other countries.

At the end of this note, I would like to advise those who are ardent admirers of novelist Haruki Murakami that a novel written anew by him was published this spring, the hero in which is closely related with railways. I hope that the novel is published as early as possible in your country.

後藤浩一

Prize Winning - UIC Innovation and Research Awards

Director Kimiaki Sasaki, Vehicle Structure Technology Division, was awarded with a prize of “UIC Innovation and Research Awards” for the development of semi-active suspensions.

The UIC Innovation and Research Awards 2012 have recently been instituted at the initiative of UIC International Railway Research Board (IRRB) to cast light on innovation to make railways safer, more economical and more environment-friendly. The Screening Committee composed of IRRB members has selected winners in six fields, safety/security, railway freight, cost reduction, railway systems, passenger services and sustainable development.

The prize for Director Sasaki was awarded for innovation in the field of safety/security. Director Sasaki’s work that was highly evaluated includes the development of a system to reduce vibration of rolling stock in high-speed areas and significant improvement in ride comfort. The results of his work are now widely used not only in Japan but also by railways in other countries including Taiwan Shinkansen.

The award ceremony was held in Paris on December 11 last year, where Director Sasaki was present, together with other prize winners and Chairman and Chief Executive Member, UIC Board of Directors.

The third person from the left is Dr. Sasaki.

Visit to RTRI by the Rt Hon Simon Burns MP, Minister of State for Transport

RTRI received a visit of important persons from the United Kingdom (UK) on 19 February 2013: The Rt Hon Simon Burns, the Minister of State for Transport, four visitors from the Department for Transport and two visitors from the British Embassy in Tokyo. The main purpose of their visit was to learn about new research and technologies related to the high-speed railway plan named HS2 in the UK.

The presentations from both parties showed possibilities of closer relationship in railway research cooperation between the UK and Japan in the near future. Prof McNaughton, Technical Director, the Department for Transport UK, made a presentation titled “Developing High Speed Rail for Britain.” Dr Iida, Director of Environmental Engineering Division, RTRI, introduced RTRI’s research activities on new noise mitigation technologies.

Moreover, RTRI showed testing facilities installed in the Kunitachi main site to the visitors. Due to time constraints, the visitors looked around only three test facilities: Ride Comfort Simulator, Test Machine for Noise Reduction Technology and Rolling Stock Test Plant. The visitors seemed to enjoy the short tour and be impressed by the quality of RTRI research activities.

The Minister and decision-makers in the UK were impressed by RTRI’s achievements and capabilities. Even after the successful achievement for Shinkansen in 1964, the first high speed railway system in the world, RTRI keeps making efforts to improve existing technologies and to find new technologies. We are looking forward to seeing how our technologies can help and support the realisation of new railway lines indispensable for activities of people in the world.

Effect of Surface Condition and Lubrication on Flange Climbing of Turned Wheels

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Flange climb derailments occur sometimes when vehicles run at low speed in sharp curves or in curves with turnouts soon after wheel turning (re-profiling). Those kinds of incidents raise concerns about the relationship between flange climbing and the surface condition of turned wheels. Thus, the author a) examined changes in the surface profile and roughness after turning, b) studied the characteristics of the coefficient of friction between wheel and rail, and c) verified through various techniques the effectiveness of the application of lubricant on wheel flanges just after wheel turning to prevent flange climb derailments.

Running tests involving the repeated passage of a vehicle were performed in a sharp curve of 200 m radius on yard track. Figure 1 shows the changes in the profile and roughness of the leading wheel's flange on the outer rail in relation to the number of vehicle passes in the curve. The figure indicates that the wheel surface, which began the test with significant roughness from wheel turning traces, became smoother after five to six passes in the curve and increased unevenness again thereafter. This trend is similar for different wheel lathe feed rates.

Figure 2 shows the results of another test using a twin-disc rolling contact apparatus to evaluate the effects of the environment and surface roughness on the coefficient of friction. A wheel-equivalent disc was tested under two roughness conditions and we obtained the following findings: (1) the equivalent coefficient of friction is larger under smooth than under rough surface conditions of the wheel disc and (2) for the smoother surface of the wheel disc, the equivalent coefficient of friction tends to increase when the relative humidity decreases. From the test results summarized in Figure 1, Figure 2 and other tests, we infer that there are increases in the coefficient of friction between wheel and rail due to an increase of the real contact area on the smooth surface and due to the wearing down of the peaks of the metallic substrata on the surface resulting from wheel turning. This phenomenon provides some understanding of the occurrence of flange climb derailments of turned wheels after running short distances.

Application of lubricant on the flat section between the flange root and toe just after wheel turning is one of the practical methods to suppress the increase in coefficient of friction due to the changes in the wheel surface condition. Figure 3 shows the results of a numerical simulation of a vehicle running in a turnout's lead curve with a radius of 100m. The coefficient of friction of lubricants such as oil is around 0.1. Therefore, it is considered that lubrication on the flange suppresses flange climbing even if the value of the coefficient of friction on inner rail is large. Running tests using lubricated wheels with oil under a test vehicle that ran repeatedly over turnouts were also performed on test tracks. The results validated the assertion that lubrication on flanges suppressed wheel climbing whereas in the case of no lubrication and dry conditions the vertical displacement of the leading wheel on the outer rail increased with the number of passes over turnouts. And the tests also confirmed the lasting effect of lubrication in a short distance (Fig.4). Furthermore, we collected and analyzed substances attached to the wheel flanges of vehicles in commercial use. We found that more than 90% of the solid matter in the substances was ferrum (Fe) which was considered as wear debris from the wheel and rails. And a laboratory test to evaluate the coefficient of friction of the substance showed that oil mixed with substances such as wear debris maintains the effectiveness in preventing flange climbing.

In summary, lubrication is an effective countermeasure to flange climb derailment at low speeds when applied to the flat section between the flange root and toe just after wheel turning. The lubrication is effective since it is able to prevent the coefficient of friction from increasing during the period of dynamic change in the wheel surface. Some railway operators in Japan have already adopted this technique for practical purposes.

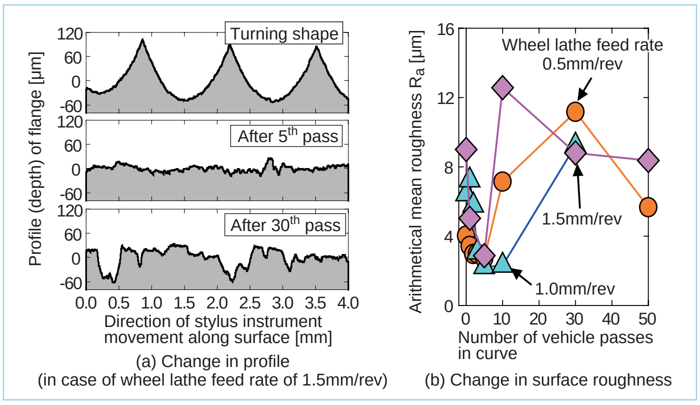

Fig. 1 Change in profile and surface roughness of wheel flange's flat section after number of vehicle passes in curve

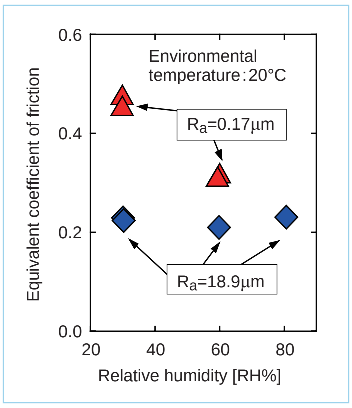

Fig. 2 Relationship between equivalent coefficient of friction and surface roughness Ra/environmental relative humidity

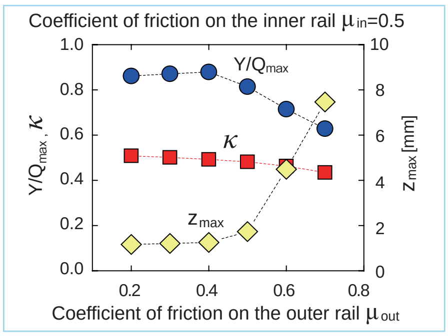

Fig. 3 Evaluation of running safety in relation to wheel/rail coefficient of friction based on numerical simulation for running on turnout

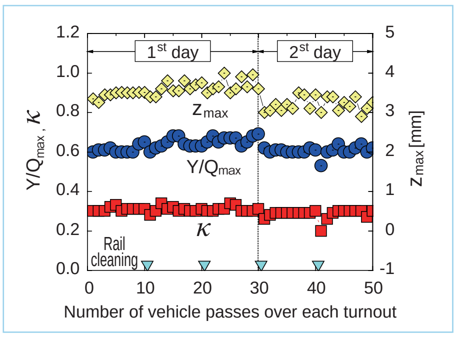

Fig. 4 Result of running test for repeated passage on turnout (in case of lubrication before running)

Y/Q_{max} : Maximum value of derailment quotient
κ : Ratio of lateral force and wheel load on the inner rail
z_{max} : Maximum value of vertical displacement of wheel on the outer rail

Development of a Pneumatic Floating Brake Caliper for High-Speed Rolling Stock

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The components of foundation brake rigging must have a simple and robust structure. The existing compact and lightweight hydraulic floating caliper that combines a floating mechanism and a direct-acting pressing (brake force actuation) mechanism with built-in hydraulic cylinders is used extensively by Shinkansen railways (Fig. 1). However, RTRI researchers are developing a pneumatic caliper that solely relies on pneumatic pressure. It will eliminate brake parts to the extent that it doesn't require a pneumatic/hydraulic pressure converter. To obtain the required pressing (brake) force with pneumatic pressure alone, however, large-size actuators and a mechanism to essentially double the pneumatic power have to be incorporated in the design.

A unique feature of the developed pneumatic floating caliper (Fig. 2) is the use of an oval diaphragm pressing mechanism to directly transmit the required pressing force using pneumatic pressure alone without using levers or wedges. The diaphragm is incorporated between the piston and cylinder to form an annular folded section. When compressed air is supplied to the diaphragm, it smoothly crawls (referred to as "rolling motion" in Fig. 3) like a caterpillar tread along the cylinder wall without sliding, thereby directly applying a pressing force proportional to the pneumatic pressure on the backside of the lining. Consequently, the caliper works as a brake force generating mechanism (Fig. 3).

The operating membrane of the diaphragm has a thickness as small as 1.3mm made of a silicon rubber coated structure of tenacious aramid fiber multiple ply ground fabric. The diaphragm can withstand a pressure of 3Mpa or approximately four times the assumed maximum control pressure of 720kPa. Although silicon rubber, which features high heat resistance, can be used continuously at 180°C, the flexibility of rubber products often changes depending on the ambient temperature. Brittleness can progress at extremely low temperature causing a loss of elasticity. Thus, it is conceivable that the function, performance and durability of silicon rubber can degrade at temperatures lower than room temperature. To address these potential concerns, we implemented a durability test (type test) and an environmental test. As a result, we found that no abnormalities occurred with the diaphragm after repeating the pressing motion 1.2 million times. This is equivalent to the number of duty cycles that normally occur over four periods of general repair and the test verified the durability is at least equivalent to that of conventional units in a room temperature environment. We also confirmed that the durability is equivalent to that of the conventional units when the operational environment is -20 to 80°C.

This was demonstrated in duty tests, implemented under the low- and high-temperature environments (-40 °C and 120°C), that were more severe than that for the conventional units. Brake operations were performed 150,000 times at each temperature environment, or 300,000 times in total to duplicate the duty cycle over one general inspection period.

In line with the design maximum brake performance to guarantee deceleration of 5.32km/h/s for a rolling stock weight of 50ton, the new pneumatic caliper achieved a stopping distance of 4,623m at a brake application initial speed of 360km/h in a life-size model emergency brake bench test (Figs.4 and 5). We also implemented emergency brake tests with the new caliper at lower speeds up to a braking initial speed of 320km/h. As shown in Fig. 5, the test verified that brake forces equivalent to or in excess of that obtained by conventional hydraulic floating calipers were achieved. The caliper remained intact as demonstrated in an inspection after the test when the caliper was disassembled.

The caliper is currently at the final stage of commercialization.

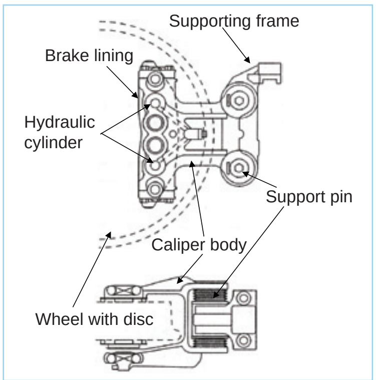

Fig. 1 Hydraulic floating caliper

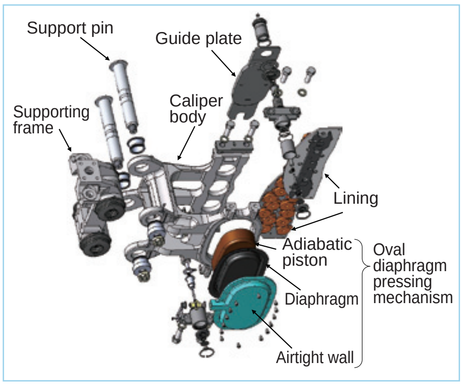

Fig. 2 Pneumatic floating caliper structure

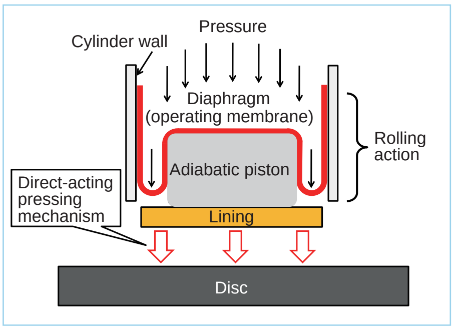

Fig. 3 Operating principle of the oval diaphragm pressing mechanism

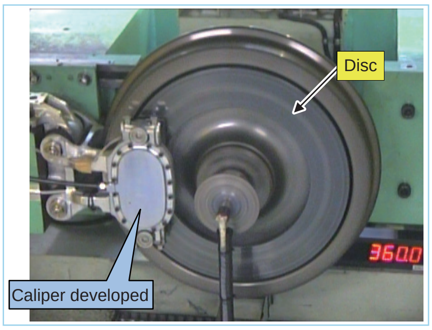

Fig. 4 Appearance of full-scale bench test

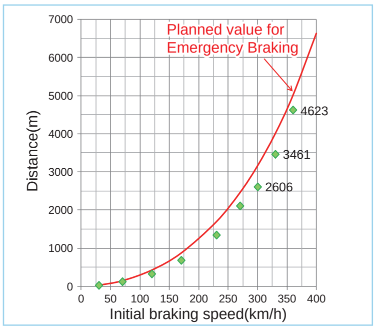

Fig. 5 Initial braking speed and stopping distance

A Technique to Analyze Passenger Flow at Transport Disturbance Using Accumulated Passenger Data

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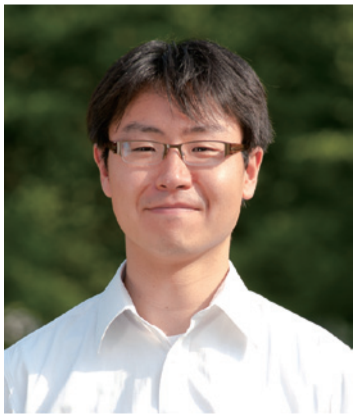
Whenever train disturbances occur, it is necessary to perform a series of adjustments such as implementation of shuttle services, suspension of trains and changing the sequence of train operation to minimize the degradation of passenger services. These actions are facilitated by correctly assessing and predicting passenger flow, but in such abnormal situations, some passengers may cancel their travels, detour to different transport facilities or take other complicated actions that were impossible in the past to assess or predict in quantitative terms. In recent years however, it has become possible to obtain recorded data in various categories related to daily train operation on a real-time basis. These data are passengers' origin-destination data (OD data) collected by the automatic ticket barrier, actual train operation time data by traffic control systems, or the number of onboard passengers by means of load compensating devices. RTRI researchers have examined techniques to quantitatively analyze and predict the passenger flow by utilizing such data when train disturbances occur.

To analyze the relation between passenger flow and train rescheduling at a transport disturbance, we devised a technique to visualize the actual data collected in the past (Fig. 1). On the rescheduled train operation diagram, this technique colors the lines according to the number of onboard passengers measured by the load compensating devices and marks with a symbol "○" the trains with substantial changes in the number of passengers compared to normal days when transport is in order. This makes it possible to easily assess the behavior of the passengers including those who shifted to the lines of other transport operators running in parallel and those passengers who were onboard the temporarily offered shuttle service trains.

As a next step, we constructed models to estimate the traffic volume in a section, or the number of passengers passing the section between two adjacent stations. We implemented multiple regression analysis using not only (1) the actual data in transport disturbances for approximately the past 10 months, and (2) the information about the place and time of the transport disturbance and the time length of the suspension, but also (3) the information about a) whether the time to resume train operation predicted and offered to users came true, and b) temporal shuttle operation in limited sections before full-scale resumption, in order to improve the precision of prediction (Fig.2). As a result, we were able to confirm that the value of the multiple correlation coefficient, an index to represent the precision of the model, took a comparatively satisfactory value of 0.7 to 0.8. Furthermore, we compared the results obtained by this model and the actual section traffic volume of two cases that were not used to construct the model (Fig. 3). Through this comparison, we were able to verify that the model is precise enough to use for making appropriate rescheduling plans before or after the resumption of train operation.



Thus, we have introduced a technique to analyze the accumulated data on the actual operation time and the number of passengers onboard the relevant trains, visualizing/predicting the passenger flow at the transport disturbance and utilizing the results thereof for decisions and discussions on train reschedulings. We will apply this technique to various lines and verify its reliability and usefulness in the future.

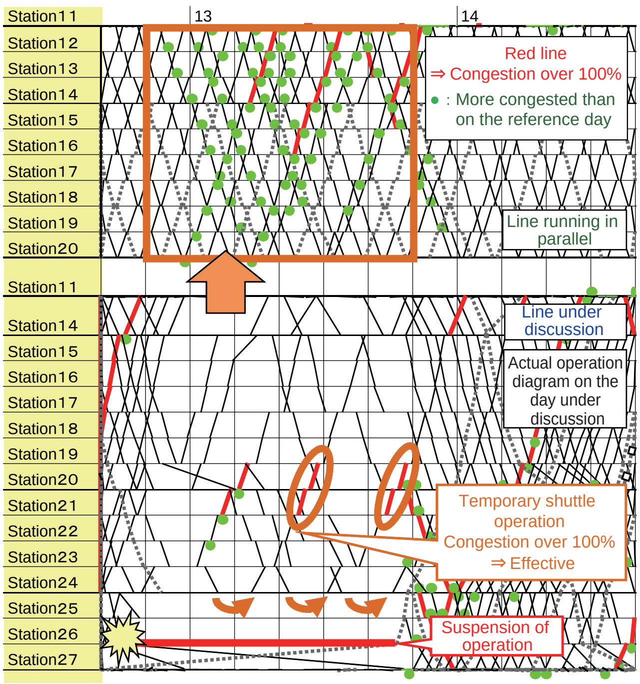


Fig. 1 Visualization of actual data

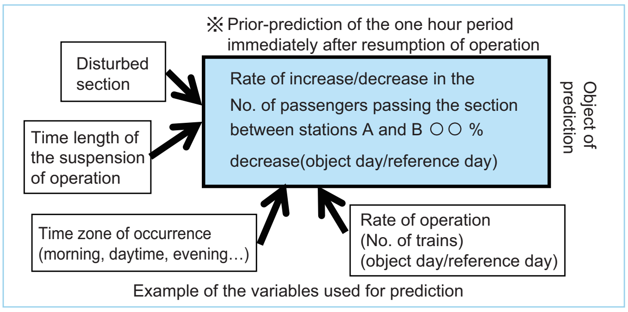


Fig. 2 A model to estimate the section traffic volume

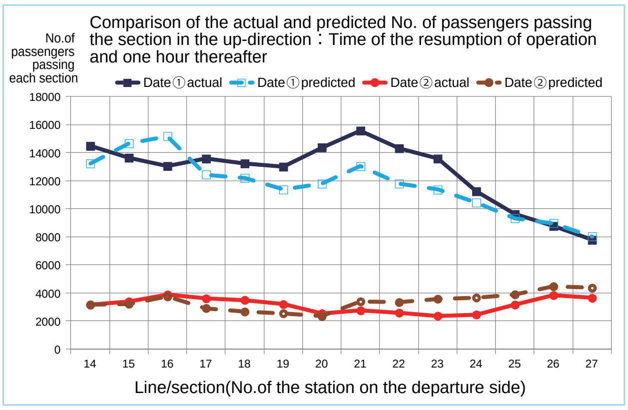


Fig. 3 Results of verification of the prediction model

A Three-Dimensional Dynamic Simulator for the Pantograph-Catenary System

Mitsuru IKEDA
Director, Railway Dynamics Division

Numerical simulation programs to calculate the dynamic behavior of the pantograph-catenary system are an extremely useful tool to design and develop pantographs and equipment/facilities of the overhead contact lines. Japan has a long history of simulation technologies in this regard. Fujii and Ebara at Tokyo University developed the first simulation program in the late 1960s to analyze the motion of the pantograph-catenary system based on the finite difference method. By means of continuous upgrade, this program is still used widely even now in Japan.

However, as the program doesn't consider the geometrical non-linearity of catenary suspension components, it doesn't correctly express the three-dimensional motion of droppers or registration arms. It also does not exactly reproduce the phenomenon of trolley wires being pulled up by the lateral tensile force at the supporting points. Thus, the Railway Technical Research Institute (RTRI) developed a new three-dimensional dynamic simulator for the pantograph-catenary system (GASENDO-FE) by applying the non-linear finite element method.

This simulator models contact wires, messenger wires and other principal wires that are little affected by the motion-induced geometrical non-linearity as linear Euler beam elements (Fig. 1). Conversely, registration arms and catenary suspension components such as droppers and hangers are modeled as bar elements to take into consideration the tangential stiffness and to reflect their geometrical non-linearity. As droppers and hangers are structured to slacken in case the uplift of the contact wire is large, this simulation program switches the natural length of dropper and hanger model according to the uplift of the contact wire.

In the actual calculation, the program first determines the static structure of the overhead contact lines based on the input data, such as the dimensions of wires and catenary suspension components and boundary conditions of messenger wire supporting points, wire termination points at the ends and registration arms fixing points. After that, the program calculates the dynamic behavior by performing step-by-step integration of the equations of motion. At each time step in the step-by-step integration, the program repeats the iterative calculations until the non-equilibrated force at each node takes the allowable small value by the Newton Raphson method. The program applies the Penalty method to calculate the contact force between contact wire and pantograph.

Figure 2 shows an example of the calculated static structure of the compound catenary system for Shinkansen. In this figure, the contact and auxiliary messenger wires are pulled up by the lateral tensile force at supporting points, as the contact wire is set with a stagger of ±200mm. Figure 3 illustrates the calculated dynamic behavior of the system when two pantographs ran beneath the overhead contact lines at 300km/h on the assumption that a lateral wind at 25m/s is blowing. The calculation indicates that the contact force fluctuates to a large extent in the vicinity of the supporting points with registration arms positioned on the windward side.

The program uses a mass-spring model to analyze the motion of the pantograph. But, it is now possible to use a multi-body model of the pantograph to analyze the motion of a pantograph alone (Fig. 4). Therefore, RTRI will combine this multi-body model with the simulator introduced above to realize simulation at higher precision in the future.

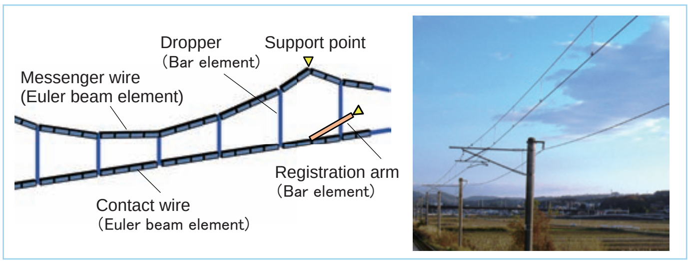


Fig. 1 FEM model of catanary system

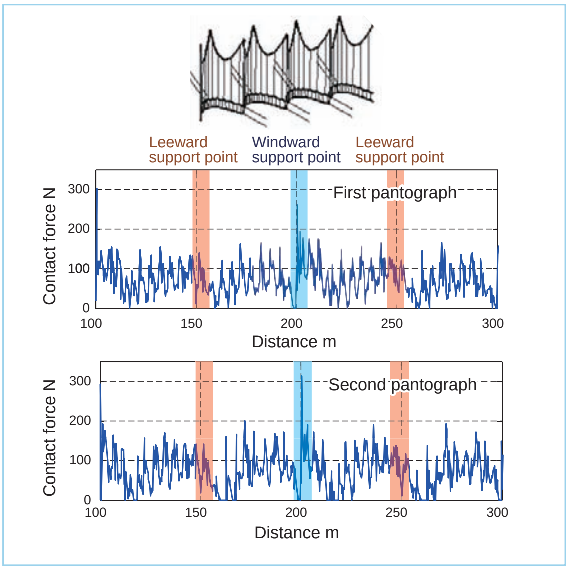


Fig. 3 Calculation result of dynamic interaction between pantograph and catenary

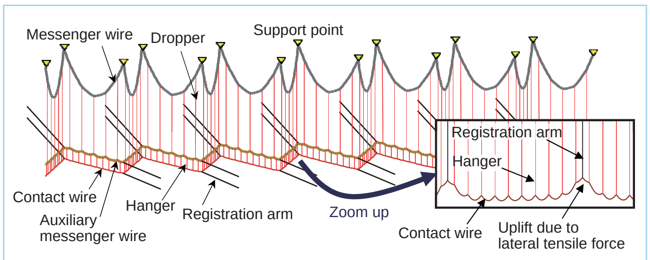


Fig. 2 Calculated static structure of compound catenary system

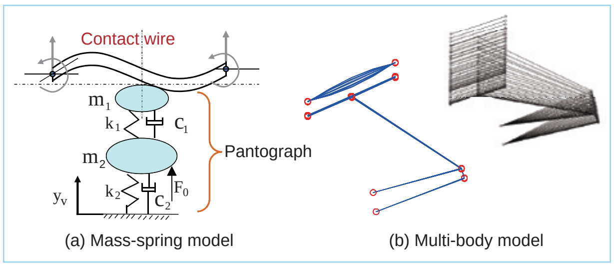


Fig. 4 Pantograph model