Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

September 20, 2012 No.40

Railway Technical Research Institute
2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN
URL:http://www.rtri.or.jp

Editorial Office: Ken-yusha, Inc.
URL: http://www.kenf.jp/en/

GENERAL INFORMATION

ARTICLES

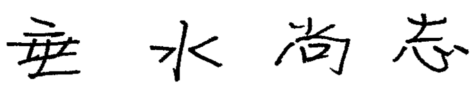
Viewpoints on the New Railway Age
- Promotion of Basic Research -

Railways are now entering a new age, powered by a paradigm shift that also affects other industries to address a) the needs of adaptation to the global environment and efficient energy utilization, b) problems arising from the low birth rates and arrival of the aging society in recent years, c) crises of the management of autonomous bodies and d) the movement to review national land utilization plans; all of this amid the unstable economy of the country affected by globalization. On the other hand, realization of the maglev system that is just around the corner, high-speed train operation over a maximum speed of 400km/h, a cabinet decision to enact the Fundamental Law on Traffic, establishment of a new overseas railway consulting company and the rapid advent of low cost carriers (LCCs), provide opportunities and challenges in the new railway age.

Under the circumstances, railways are now required to push forward improved quality initiatives, including development of a derailment-free rail transport system, increase of the robustness against external forces created by natural phenomena, solutions for energy and the environmental issues, repair/replacement of aged structures and so on. To further improve the quality of the wheel-rail transport system for Japan which has already attained very high levels in technologies, basic research shall be promoted both on hardware and software technologies simultaneously. In regard to the natural phenomena surrounding railways, demanding tasks include developing countermeasures against the disasters caused by large-scale earthquakes and wind gusts. Research shall be promoted to investigate those characteristics; strong motion due to active faults and the occurrence mechanism of wind gusts. Based on these fundamental research programs, the accuracy of the early earthquake warning system and forecast of gusts will be improved. In the structural engineering field, investigation of the phenomenon of deterioration and innovative repair/reinforcement countermeasures for aged structures are required. It may be necessary to consider and adopt new indices and review fracture criteria to effectively investigate the effects of these phenomena. In addition, the deterioration of the materials used for rolling stock and infrastructure, performance of current collecting systems, effect of external forces on rolling stock behavior and the interactions between structures and vehicles, are important themes to achieve train operations over 400km/h. To properly assess the behavior of high speed trains, it is necessary to construct a high-performance test track simulator that will complement the tests on actual and test tracks. The results obtained from the research will be reflected in the maintenance standards of rolling stock and infrastructures.

RTRI continues the effort to accelerate the basic research realizing a further upgraded railway system to enhance the value of railways.

Hisashi TARUMI
President



High-Speed Rail Development for the Next Generation UIC Highspeed 2012 held in Philadelphia, USA in July 2012

Hiroyuki SAKAI
General Manager, International Affairs, International Affairs Division

In a couple of years we will see the 50th anniversary of the first advent of high-speed rail in the world, achieved in 1964 by Japanese National Railways (JNR). Afterwards, French National Railways (SNCF) developed the TGV system while JNR and Japan Railways, organizations created by privatized JNR, improved the Shinkansen high-speed rail system. After the introduction of TGV, the system of TGV was installed into Korea Railroad (KoRail) in 2004 with the name fondly called KTX. The Shinkansen system was also implemented in Taiwan in 2007. China Railway bought high-speed rail systems from Japan Railways, SNCF and other railway companies in Europe and constructed a high-speed rail system in 2011. Currently, the total service line length of operating high speed lines in the world is 17,547 Km, while under-construction and planned lines are 9,289 Km and 15,476 Km, respectively. Thus, we have already seen the next stage of high-speed rail development which began after the beginning of this century 12 years ago when the basic high-speed rail systems began to be implemented.

The US is a country where high-speed rail systems are planned as an intercity mass-transportation system. Some large urban areas also have plans to introduce high-speed rail systems. The State of California is expected to construct a high-speed rail line. The 8th World Congress on High Speed Rail or UIC Highspeed 2012 was organized by International Railway Union jointly with American Public Transportation Association and was held in Philadelphia, US in July 2012. Only five days prior to the conference, the California State Government decided to prepare a budget to construct a high-speed track for Amtrak to prepare for high-speed operation in the future. The meeting, therefore, was timely. To lead and direct the discussion at the meeting, CEOs visited the US from Japan Railways, Taiwan High-Speed Rail, KoRail, China Railway and SNCF, all leading companies developing or operating high-speed rail systems. About 1,000 participants joined the meeting from 37 countries, including 184 speakers.

RTRI or Railway Technical Research Institute provided two speakers to the meeting to introduce specific technologies for high-speed rail operation. In consideration of the meeting venue of the US, RTRI gave a paper on how to successfully plan a new high-speed railroad track in countries subjected frequently to earthquakes. California is one of the places where high-speed rail is expected in the US and is also frequently hit by earthquakes. Mr. Murono presented his technologies and experience to successfully implement high-speed line planning to avoid or reduce damage to be caused by earthquakes. This is perfect timing to indicate his concept to the people in the US, who want to bring high-speed rail systems to California. In his session, they enjoyed discussions on how to direct high-speed rail construction even in an earthquake "nest" such as California. The technologies should be helpful to California when the first section of the Amtrak training line is constructed and when it is extended as a real high-speed service line.

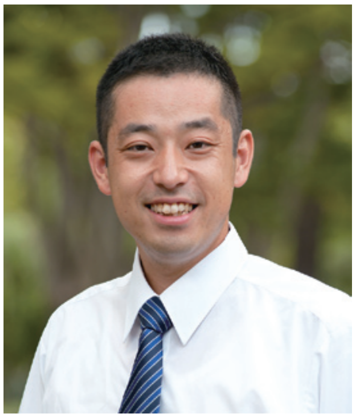
At the meeting, a key phrase, "the next generation" was stressed. This means that high-speed rail systems have already been established, with those concerned now looking for places where the systems are to be installed. They believe that the systems will bring the next generation easier and faster transportation services as a heritage from the current generation, resulting in a prosperous society to be technically and financially supported with such passenger rail services. Thus, their goal for high-speed rail development is to be for "the next generation."

Fig. 1 Mr. Murono showing his paper on successful planning of high-speed rail in an area where earthquake shocks are anticipated

Fig. 2 Participants from RTRI, enjoying a ride of a special train organized by the host for the welcome reception venue

Diagnostic Technology to Improve the Upkeep and Maintenance of Railway Tunnels

Kiwamu TSUNO
Assistant Senior Researcher, Tunnel Engineering, Structures Technology Division



Railways in Japan began to attach more importance tunnel upkeep and maintenance after they experienced accidents due to deterioration and failures of concrete linings in 1999. In Japan, railway tunnels are all subject to regular and general inspections. This requires railway operators to expend considerable manpower and time, particularly as tunnels are numerous and are scattered across the country. Most of the inspections are carried out manually and problems occur with differences in judgment between inspectors. Inspectors normally rely on manual measurement in monitoring deterioration (sometimes known as metamorphosis) of concrete.

As a first step to raise the quality and consistency of judging tunnel soundness, and to make the inspection objective and automated, RTRI developed a new tunnel soundness diagnosis system (TUNOS). See Fig. 1 for the total flow of the system. This system automatically extracts information on cement deterioration and crack patterns, including closures, intersection and parallelism of cracks, and judges the soundness level (α, β or γ) against flaking, while reflecting the existence or non-existence of water leaks and the results of hammering tests. Based on the results of collation with crack patterns and the possibility of deterioration to occur, the system also extracts damage due to external forces, automatically determines their causes and judges the soundness level (A, B, C or S) against the damage generated by external forces. The crack patterns are classified by the damage caused by external forces as a function of biased, plastic and vertical pressures. The system then lists combinations of possible cracks and summarizes the positions of cracks and compressive fractures (breaks) belonging to each pattern. The results of the diagnosis are output in two different formats: one is a package display of approximate soundness levels for different spans and the other is a presentation of the detailed data at a specified point when the “DETAIL” button corresponding to the point is pressed (see Fig. 2).

One reason why automatic measurement has rarely been adopted for long-term tunnel monitoring so far is because the cables between sensors and tunnel mouths require enormous amount of manpower and funding for laying and maintenance. Therefore, RTRI developed a radio system for transmission of measurement data to the tunnel mouths from the sensors installed on the lining of the tunnels. See Fig. 3 for the developed data transmission system and Fig. 4 for a radio sensor used for the system. The radio sensor, driven by FR lithium batteries is as compact as 100g in weight and 10 x 10 x 3.5cm (including batteries) in size. RTRI has used the system to measure crack widths and temperature, at approximately eight minute intervals, in an actual tunnel and confirmed its practical applicability. RTRI also implemented a long-distance transmission test using relay radio sensors at another tunnel and verified the applicability of transit data transmission. A technology to process measurement data accumulated in quantities has also been developed by RTRI as well as a method to predict deterioration in the future based on the data. The technology makes it possible to implement automatic measurement for long-term deterioration monitoring.

RTRI believes that the developed tunnel soundness diagnosis system, along with the deterioration monitoring technique to use radio sensors introduced above, will effectively contribute to a high level of upkeep and maintenance of railway tunnels.

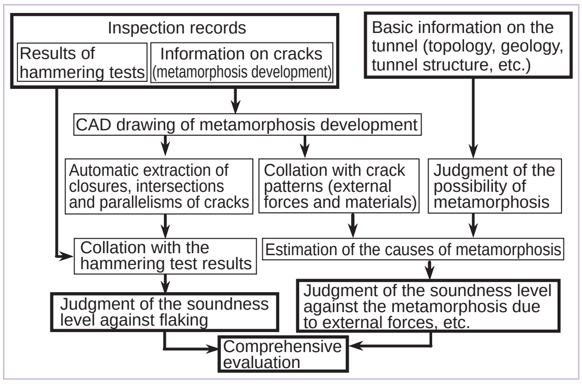


Fig. 1 The total flow of the soundness diagnosis system

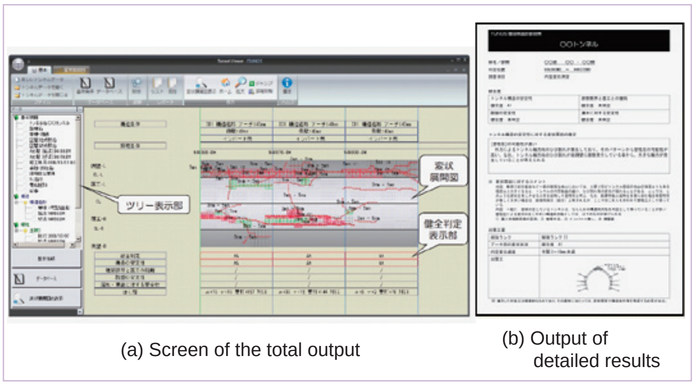


Fig. 2 Examples of the display screen of the diagnosis results

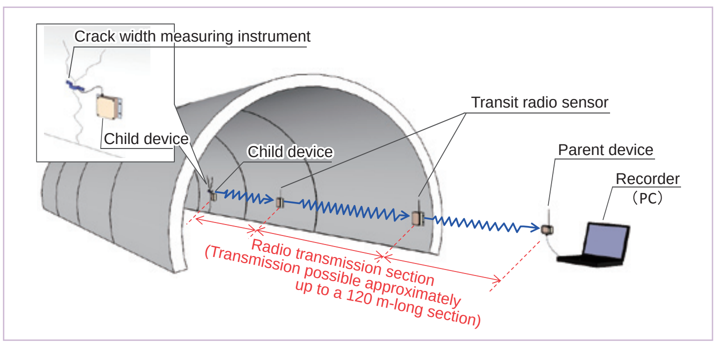


Fig. 3 Monitoring system to use radio sensors

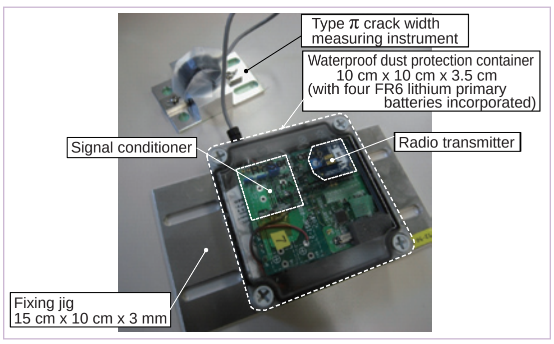


Fig. 4 Developed radio sensor

Development of a System to Support Energy Saving Train Operation

Kazumasa KUMAZAWA
Researcher, Transport Operation Systems, Signalling and Transport Information Technology Division

A means to reduce energy consumption in train operation is to develop efficient methods to run trains. This can be achieved rather simply without changing rolling stock equipment or train schedule. To support discussions on such train operating methods, we are now developing a system to demonstrate alternative train operation methods featuring reduced energy consumption.

1. Train operation and energy consumption

For trains running between stations, the current method of train operation (timing of acceleration, coasting and braking) solely relies on the experience and judgment of train drivers. Just as driving automobiles differs from person to person, so does the operation of trains. A diagram called a train performance curve is normally used to analyze the performance of running trains. These illustrate the movement of a train according to the method of operation, with the X-axis representing distance and the Y-axis train velocity. Figure 1 shows two train performance curves obtained by running a train in a certain section by two different methods. This Figure indicates that the running time is the same with the two methods, but the quantity of consumed energy differs significantly. This proves that we can reduce the quantity of energy used for train operation by developing appropriate methods to operate trains.

2. Evaluation of energy consumption based on the theory of train operation

Consideration of train operation methods with reduced energy consumption requires the following simulation and evaluation:

(1) Simulation of different methods of train operation,

(2) Evaluation of the energy consumption for these different train operation methods.

To simulate train operation, we can apply the theory of train operation to dynamically calculate a train performance curve under the specified train operating method while considering track and rolling stock conditions.

After determining the running conditions of the train at various points with the aid of train performance curves, we can link them with the train's energy consumption data to subsequently calculate the quantity thereof. In this manner, we have developed a system to evaluate the quantity of energy consumption based on the theory of train operation. See Fig. 2.

3. Search for energy saving methods of train operation

We are now developing a system to search for methods of train operation with smaller quantities of energy consumption by applying the above-mentioned system to evaluate the quantity of energy consumption. As a prerequisite to do so, however, we have to consider the running time between stations to ensure that trains shall run according to the time schedule set forth on train schedule.

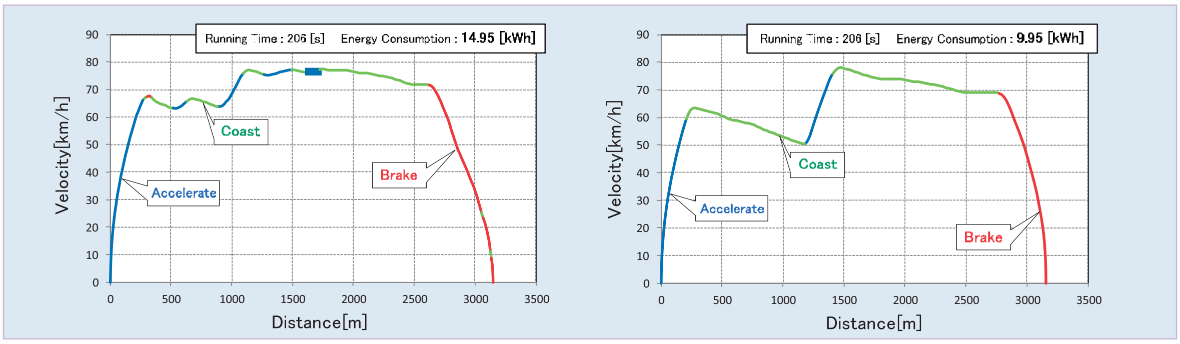


Fig. 1 Train operating methods and quantities of energy consumption

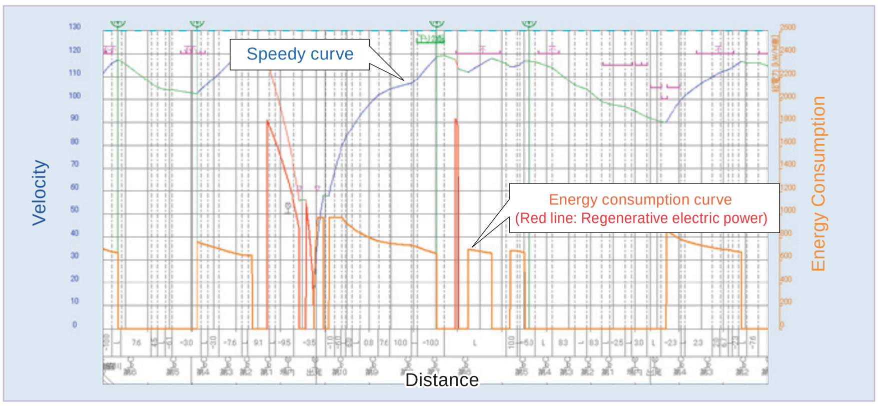


Fig. 2 The system to evaluate the quantity of energy consumption

Evaluating Train Rescheduling Methods to Reflect Passenger Dissatisfaction

Kana YAMAUCHI
Senior Researcher, Ergonomics, Human Science Division

In Japan, railways play a vital role in transporting people in and between metropolitan areas. In many instances, trains are operated every few minutes to transport a vast number of commuters, yet Japanese railway operators have a worldwide reputation for punctuality. However, in recent years, there has been a long-term rise in the frequency of "transport disorder," defined as train delays of 30 minutes or more, on Japanese urban railways. This has become a serious social problem. The problem manifests itself in the form of significant train delays spread over a wide service area. This can be affected by recession-related suicides on the line and by the expansion of through-operations between different railways, intended to enhance travel convenience.

In order to restore disrupted services, a series of modifications to the current train schedule has to be completed. Such a task is called train rescheduling.

However, currently we do not have refined and established criteria available for this task because there are too many aspects to consider such as the scale of train traffic disruption and the extent of passengers' inconvenience. The effect of train rescheduling has been measured in the past based on such indices as "train delays" and "time required to restore normal train traffic." Such indices are useful to macroscopically assess the effect of disordered train operation, but not to measure detailed change brought about train rescheduling. To assess the effect of train operation disorder more precisely from the viewpoint of the passengers, attempts have been made in recent years to develop evaluation indices to reflect the dissatisfaction and inconvenience of passengers. However, the proposals to date do not directly deal with passenger dissatisfaction as it applies to rescheduling train operation. It has not been clarified either, to what extent they correspond to the dissatisfaction of those who actually encounter disruption in the service. Under the circumstances, therefore, RTRI implemented the following developmental activities.

(1) Measurement of the dissatisfaction of those who have been involved in train disruption through a questionnaire survey on the Internet.
(2) Construction of a model to explain the hitherto unknown process in which dissatisfaction is generated. We call it Passenger dissatisfaction determinant model as shown in Fig 1. The model is constructed based on the data collected in (1). It is also clarified that evaluation by passengers of the information provided by railway operators largely affects the dissatisfaction against the railway services on the day.
(3) Proposed formulae (Table 1) to calculate passenger dissatisfaction by using data collected in (1).
(4) Development of a method to evaluate the train rescheduling. By introducing a simulation system that can simulate the behaviour of passengers, we can calculate and visualize the values of indices as shown in Fig 2.

This method can quantify the effects of the detailed modifications that compose the train rescheduling. Consequently, it is applicable to post-analysis of the already implemented train rescheduling, and can provide useful knowledge in sharing problems and knowledge among train dispatchers.

We would like to conduct further surveys on different lines and/or in several distinct types of disruption in order to improve the precision of passenger dissatisfaction estimation. We also plan to develop a refined simulation technique to achieve precise and fast predictions of train traffic and passenger behaviour.

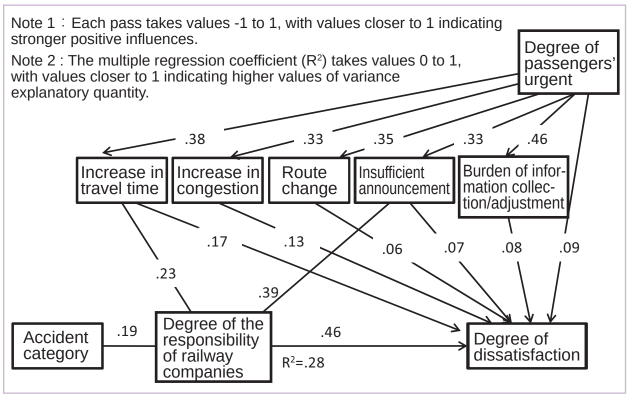


Fig. 1 Passenger dissatisfaction determinant model

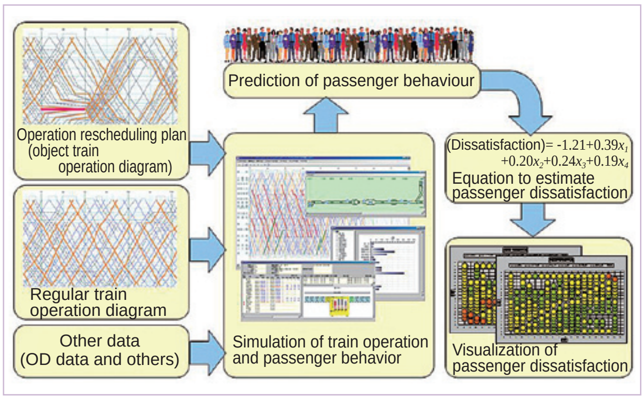


Fig. 2 The method to evaluate the train operation rescheduling service to reflect passenger dissatisfaction

Table 1 Formulae to evaluate the train operation rescheduling plans

Passenger dissatisfaction = $-1.21 + 0.39 X_1 + 0.20 X_2 + 0.24 X_3 + 0.19 X_4$ (R^2=0.30)
X_1: Subjective quantity for the increase in the required time (r=0.55) X_1 = 2.69+2.46 {log (1+required time on the day)-log(1+normally required time)}+0.26(cancellation of train operation)+0.32(degree of haste)
X_2: Subjective quantity for the increase in the waiting time (r=0.65) X_2 = 2.20+1.12{log(1+waiting time on the day)−log(1+normal waiting time)}+0.22(cancellation of train operation)+0.32(destination change)+0.23(degree of haste)
X_3: Subjective quantity for the increase in the degree of the congestion in trains (r=0.62) X_3 = 2.37+0.02 {log(1+degree of congestion on trains on the day)-log(1+normal degree of congestion on trains)}+0.27(cancellation of train operation)+ 0.28(degree of haste)
X_4: Subjective quantity for the increase in the frequency of transfer (r=0.79) X_4 = 1.89+1.44 {log(1+frequency of transfer on the day)-log(1+normal frequency of transfer)}+0.34(cancellation of train operation)+0.14(degree of haste)

Factors that Influence the Adhesion Coefficient between Wheel and Rail

Hua CHEN
Senior Researcher, Track Dynamics, Railway Dynamics Division

In rain or snow, the adhesion (friction) force between the wheel and rail often decreases due to the lubricating action of the water film existing between the two surfaces. Wheels slip when the adhesion force is smaller than the driving force during acceleration and wheels slide when the adhesion force is smaller than the braking force during braking. These phenomena create operating concerns through poor braking or acceleration performance and cause slipping or sliding flaws on the wheel/rail contact surface, which can increase noise and vibration when trains run. To remove these surface flaws, wheel treads are often turned and rails are usually ground. When wheel tread and rail surfaces are seriously damaged, wheels and rails are replaced. Thus, this surface damage inevitably contributes significantly to the maintenance costs of railways. To ensure the safety and stability of transport and save the maintenance costs, we undertook a program to quantify the factors that affect the adhesion force under wetting conditions and find measures to suppress the decreases thereof.

In this study, we accounted for the factors that seemingly influence the adhesion force under wetting conditions, such as train running speed, wheel loads, surface roughness of wheel/rail and water temperature. We studied the degree of influence of each factor through a numerical analysis applying the mixed lubrication theory and through laboratory tests using a two-disc rolling contact machine. As a result, we were able to clarify that running speed, water temperature and surface roughness have comparatively large effects on the adhesion coefficient.

See Fig. 1 for a numerical analysis model for the case where a water film exists between wheel and rail. Figure 1 assumes a state of mixed lubrication where some metallic solids are in direct contact with each other and coexist with those in contact with a water film sandwiched in between the solids. In Fig. 1, Wc denotes the load supported through roughness protrusions in contact and Wh the load supported by the water film. The adhesion coefficient μ is given by the following equation.

$$\mu = \frac{\mu_c W_c + \mu_h W_h}{W}$$

Where:
μ_c : Boundary friction coefficient at the contact surface between metallic solids
μ_h : Shear coefficient of the water film
W : Wheel load

We applied the elastohydrodynamic lubrication theory and used a Greenwood - Williamson rough surface contact model (with the heights of roughness protrusions assumed to follow a Gaussian distribution) to obtain the solutions of numerical analysis through the Newton - Raphson iterative procedure. Figures 2 and 3 show the results of the numerical analysis induding the relations between water temperature, surface roughness and adhesion coefficient. These Figures indicate a trend that higher values of water temperature and surface roughness result in increased values of adhesion coefficient.

Figure 4 shows the contact between wheel and rail specimens of a two-disc rolling contact machine together with a water injection system used in this study. Although it would have been desirable to set the same speed as that used in the numerical analysis for high-speed trains, we set the maximum speed at 100 km/h as this was the limit of the testing machine. Figures 5 and 6 show the test results including the relations between water temperature, surface roughness and the maximum traction coefficient (equivalent to the adhesion coefficient). We were able to confirm that as water temperature or surface roughness increases, the adhesion coefficient follows suit. This is the same as the result obtained through the numerical analysis.

Based on the above results obtained through a theoretical analysis and laboratory tests, we can conclude that, if practically possible, it is effective to increase the temperature of the water film existing between wheel and rail or the wheel/rail surface roughness as methods to suppress decreases in the adhesion coefficient between wheel and rail under wetting conditions.

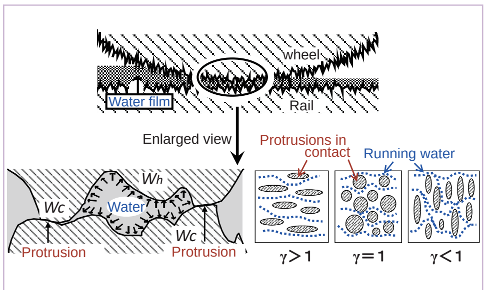


Fig. 1 Numerical analysis model of wheel/rail

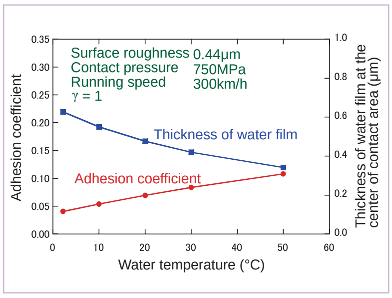


Fig. 2 Relation of water temperature versus adhesion coefficient

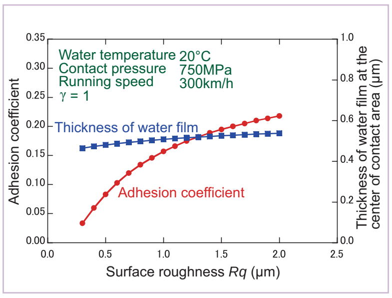


Fig. 3 Relation of surface roughness versus adhesion coefficient

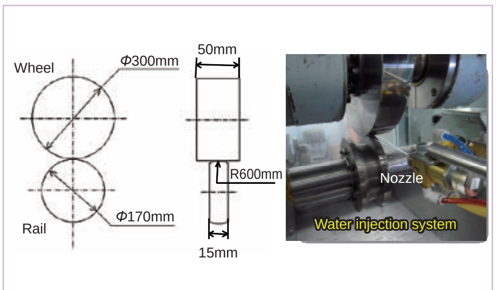


Fig. 4 Test specimens of the two-disc rolling contact machine installed with water injection system

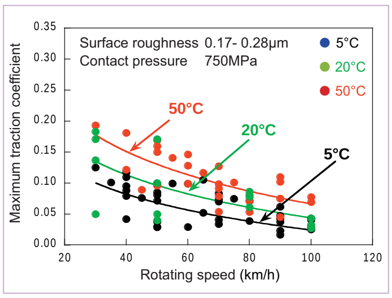


Fig. 5 Relation between water temperature versus the maximum traction coefficient

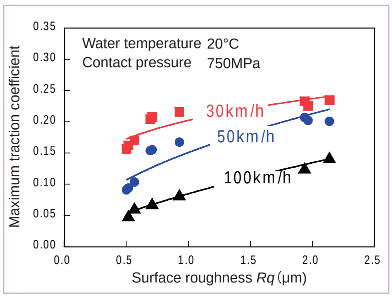


Fig. 6 Relation between surface roughness versus the maximum traction coefficient