Newsletter on the Latest Technologies Developed by RTRI

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Support for the Safety of Train Operation

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Executive Director

The railway network in Japan covers a total length of approximately 27,500 km, over which about 200 railway operators run passenger and/or freight trains on a daily basis. These railway operators are extremely diversified in scale and corporate power; as an example, JR East (the largest railway company in the country) claims a mammoth-size network of approximately 7,500 km, while one of the smallest railway companies in Japan operates a route length of just 2.7 km in a rural area.

To ensure the safety of train operation, safety devices, such as the ATS system to prevent trains from passing red signals, have been installed on all railway lines except tramways in Japan. Furthermore, installation of new systems is now being introduced at terminals and at locations with sharp curves to prevent trains from exceeding speed limits. It becomes therefore now a major issue for railway companies who lack adequate funding for investment.

RTRI is now making efforts to develop not only high-level safety systems for Shinkansen and high-density train operation lines but also low-cost safety systems that are appropriate for railways with lower levels of traffic.

As enhancement of safety systems alone is insufficient to eliminate all train accidents, RTRI is also promoting R&D on human factors related to train drivers and staff closely involved in railway operation.

It is also developing new aptitude tests for those engaged in train operation, techniques to enhance safety awareness in the workplace and methods to evaluate work schedules that take into consideration the issue of long-term accumulated fatigue among operating staff. At the same time it is promoting research themes over a wide range of areas.

RTRI welcomes requests for consultation on routine problems from railway operators who cannot employ sufficient numbers of engineers, and it makes available advisers to them to provide support for troubleshooting. Consequently, RTRI's mission is not only to promote the most advanced technological developments within its organization, but also to offer technological services to railway operators based on its wide-range of knowledge in order to offer comprehensive support for the safety of train operation by railways across the country.

A Life-Size Station Building Model

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A principal means of discussing the flow and comfort of passengers at stations has so far been to observe phenomena in actual station yards. In order to elucidate the characteristics of passenger flow in emergency situations, however, experimental tests under various conditions are necessary. Accordingly, the Railway Technical Research Institute (RTRI) has developed a life-size station building model (Figs. 1 and 2) for use in such tests. It can be used to conduct passenger flow tests, evaluation tests for guidance signs or guidance announcements, subjective evaluation tests on the effects of thermal and acoustic environments, and continuous measurements.

The model simulates an over-track station with an internal size of about 15 x 16 m, a ceiling height of 3.5 m (and partially 6 m) and two staircases. The height of the floor from ground level is 4 m, which is approximately the height of the concourse floor in real-life stations from platforms. As the interior materials are those used at actual stations, simulation participants feel as if they are in a real station in terms of visual input.

The experiments that the RTRI has implemented or plans to implement are as follows:

● Passenger flow experiments

The RTRI has conducted experiments on how factors such as congestion density on concourses and staircases affect ease of walking for passengers. In these experiments, the Institute changed congestion density while varying spatial conditions such as staircase widths and obstructions representing small stores or elevators. Based on the test results, the RTRI developed a technique to evaluate passenger flow in stations.

Fig. 1 External view of the station building model

● Evacuation experiments

The RTRI has conducted evacuation experiments related to the inner space of the station building model in darkness, representing a state of power supply failure in an underground station due to an earthquake or other incident (Fig. 3). Although these experiments remain at the basic stage, the Institute plans to advance the development of an evacuation guidance method by utilizing related visual and acoustic information.

●Experiments to evaluate flooring materials

The RTRI has evaluated the relationship between the friction coefficients of surface floor materials and passengers' perception of slipperiness using several types of flooring aligned within the station building model (Fig. 4). The Institute carried out the experiment under dry and wet conditions assuming rainy weather, and proposed values for use as evaluation criteria under each condition.

●Experiments on the ease of hearing public address system announcements

The RTRI is conducting experimental tests on the relationship between the volume of guidance announcements and the ease with which they can be heard, as well as how differences in sound-absorbing materials or speaker arrangement affect ease of listening.

● Experiments on passenger comfort

Regarding factors such as thermal, acoustic and odor environments that affect the comfort of passengers on station concourses, the RTRI is conducting subjective evaluation tests using trial subjects as well as verification tests on the effects of comfort-improving methods. Regarding thermal environments, in order to reduce discomfort in summer without the use of air conditioning, the Institute has conducted a measurement experiment on the effect of the position/size of openings on station concourse thermal environments by creating a number of openings in the station building model.

In order to create safer and more comfortable stations, the RTRI plans to further promote research and development using these experimental facilities.

Fig. 2 Internal view of the station building model

Fig. 3 Evacuation test (walking experiment in darkness)

Fig. 4 Floor material evaluation test (walking experiment on wet floor materials)

Development of Quakeproof Reinforcement Methods for Masonry Walls

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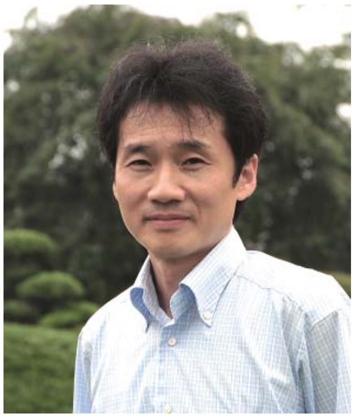

Railway lines in Japan are sometimes flanked by earth-retaining structures consisting of piled-up stones, known as masonry walls (see Fig. 1). Although railway operators are aware that these walls can collapse and damage trains in the event of an earthquake, the behavior of such structures when subjected to seismic motion has not yet been clarified. Against this background, the Railway Technical Research Institute (RTRI) investigated the deformation mechanism of masonry walls in earthquake conditions. Based on the results of this research, a technique called the pin-up method was developed to effectively reinforce masonry walls against earthquakes.

A model collapse test on a masonry wall revealed that its backfill cobblestones slid outward due to the relative movement between the ashlars on the front and the ground behind, thereby generating residual displacement in the wall. In view of these deformation-causing factors, the earthquake resistance of masonry walls is expected to improve if the movement of backfill cobblestones can be suppressed. It is therefore thought that measures to fix these cobblestones using grouting materials will provide an effective means of helping masonry walls to resist earthquakes. However, these cobblestones play a role in draining water that penetrates the ground, thereby preventing it from applying pressure to the backside of ashlars. If grouting material is injected into the backfill cobblestone layer at random, this drainage function may be lost. The RTRI therefore designed the pin-up method (types I and II) to enable the suppression of backfill cobblestone movement while maintaining its drainage function (see Fig. 2).

Type I of the pin-up method combines four adjacent ashlars and the backfill cobblestones in the wall behind them to create stiffening blocks, thereby achieving the goal of improving the earthquake resistance of the masonry wall while maintaining the drainage function of the backfill cobblestones and suppressing their movement. Type II, on the other hand, also anchors the combined stiffening blocks to the ground using deformed bars, and is applied when the level of earthquake resistance required is higher than that offered by type I. Pin-up method types I and II are so named because they can be likened to fixing masonry walls to the ground with pushpins.

Figure 3 shows the results of shaking table tests to verify the effect of earthquake reinforcement work applied to model masonry walls using pin-up method types I and II. When the models were subjected to sinusoidal wave excitation at a maximum acceleration of 7 m/s^2, deformation was suppressed to one-third or less that of a non-reinforced wall with the model reinforced using pin-up method type I. On the other hand, the model reinforced using type II showed virtually no deformation at all.

As these test results demonstrated that masonry walls reinforced using the pin-up method have a high level of earthquake resistance, the RTRI discussed concrete methods of reinforcement in consideration of actual conditions, clarified the quality of applicable grouting materials and decided on suitable methods of injection. Based on the results of model tests, the Institute also determined methods to evaluate the degree of deformation in masonry walls in earthquake conditions, evaluate their stability and design reinforcement work using the pin-up method. By summarizing these study results, the RTRI was able to create a manual for design and reinforcement work related to masonry walls.

In January 2009, the pin-up method was applied in actual masonry wall reinforcement work for the first time (see Fig. 4). The RTRI will strive to promote the adoption of this method over wide areas in order to contribute to the improvement of disaster prevention for railway wayside slopes.

Fig. 1 A view of masonry walls along railway lines

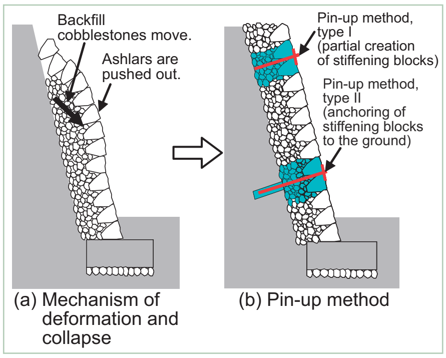

Fig. 2 Schematic view of the Pin-Up method

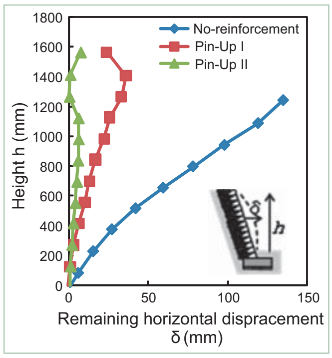

Fig. 3 Distribution curves of lateral residual displacement

Fig. 4 Appearance of reinforced masonry wall

Mechanical Performance Analysis of a Switch-and-Lock System for Shinkansen

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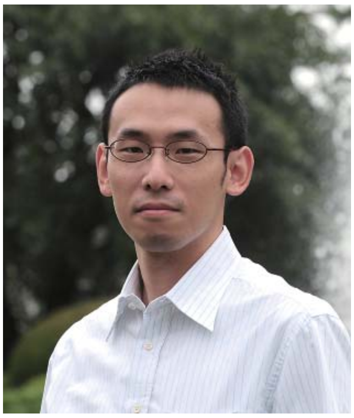


In the development and redesign of the switch-and-lock system (composed of an electric switching machine and switching equipment) to ensure its safety and reliability, it is important to check a number of mechanical properties including the force required to bring about switching (referred to here as the switching load) and performance in the detection of foreign matter captured between the tongue rail and stock rail. To this end, we are currently implementing performance confirmation testing on actual switch-and-lock systems combined with turnouts, which requires tremendous amounts of time and money. Furthermore, it is very difficult to perform tests for all combinations of switch-and-lock systems and turnouts due to the sheer numbers involved.

In redesigning and developing more efficient switch-and-lock systems to meet today's needs for reduced costs and streamlined maintenance work, it is essential to improve the efficiency of the development process (Fig. 1). Against this background, we are now working on the development of a dynamic model to estimate switching loads while aiming to establish a technique to analyze and evaluate the mechanical performance of switch-and-lock systems to replace such measurement tests.

Figure 2 shows the composition of a Shinkansen switch-and-lock system. The system adopts a setup that makes use of an electric point machine and plural escape cranks (to switch plural spots of tongue rails). This type of switch-and-lock system has the characteristic of being subjected to shock from high-speed trains by the escape cranks (rather than directly by the point switch machine) in order to ensure a high level of safety. This switch-and-lock system involves switching equipment including signal links that mediate between the electric point machine and the tongue rail, meaning that the switching load is affected by the dimensions and configuration of this switching equipment (e.g., the diameter and length of signal links and switch adjusters).

We have therefore developed a model to estimate the transmission of switching loads in switching equipment (Fig. 3). The model is made up of elements corresponding to signal links, switching adjusters and escape cranks. In its development, we assumed that the dimensions and configuration of the signal link and the switching adjuster affect the elastic and damping coefficients, while those of the escape crank affect the transmission torque, which changes depending on the contact condition.

As an example of the model's application, Fig. 4 shows the switching load calculated using the model after redesign of the configuration of the escape crank on the end side. It turns out that the maximum switching load is reduced by using the redesigned crank as compared to the conventional one. This finding corresponds with the test results obtained from actual systems.

These results suggest that measures can be implemented to cope with switching disability (a type of failure that occurs when the switching load is larger than the switching power of the electric point machine) by redesigning switching equipment. In the future, we plan to promote the development of a dynamic model that considers the effects of friction force and tongue rail elasticity, and to improve the simulation precision of the dynamic model. We will then propose an analytical means for dealing with problems caused by increased switching loads.

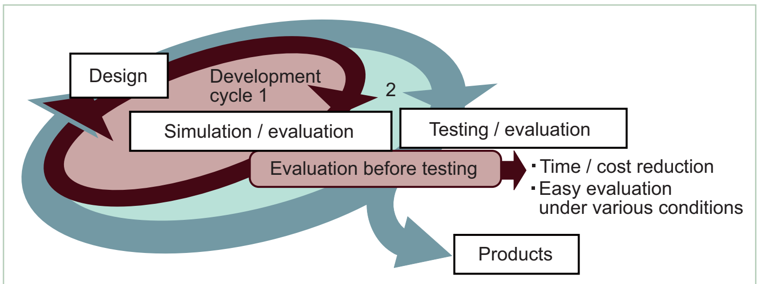
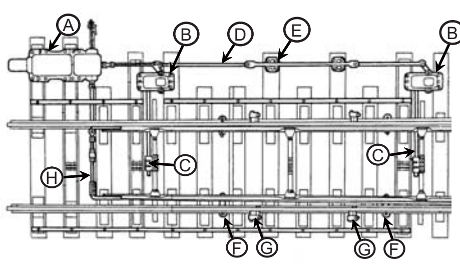


Fig. 1 Development process of switch-and-lock system (proposed)



A	Electric switching machine
B	Escapement crank
C	Switch adjuster
D	Rod
E	Rod carrier
F	Roller
G	Circuit controllers (contact detect type)
H	Front rod

Fig. 2 Composition of Shinkansen switch-and-lock system

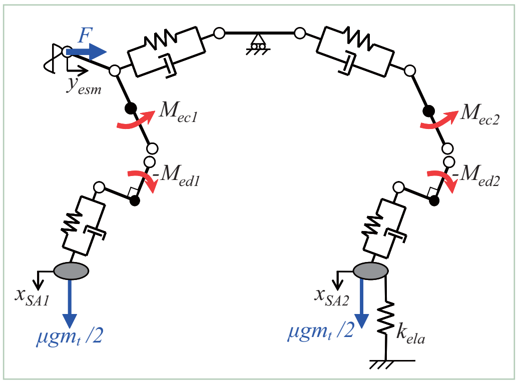


Fig. 3 Switching loads transmission model

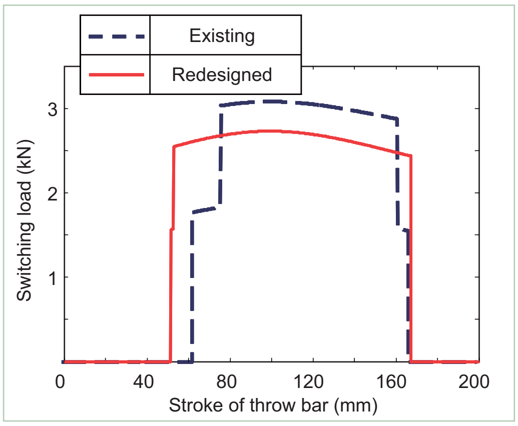


Fig. 4 Result of switching load calculation

An Algorithm for Rescheduling Freight Train Locomotives and Drivers

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Freight trains operate over long distances through different areas; making them susceptible to large-scale disorder caused by transport disturbances in particular regions. In such situations, timetables are adjusted by delaying or cancelling trains as necessary, which requires the rescheduling of locomotives and the reassignment of drivers to trains. Figure 1 shows an example of timetable adjustment in which three trains are delayed by about three hours at the departure of Station U and one is cancelled. The red line in the figure shows the duty of a particular driver, and demonstrates that he/she will miss the next train to drive. The rescheduling process has so far been entrusted to manual work by the dispatchers in charge, and there is a need to speed up rescheduling in response to disruptions and to reduce the related staff workload.

To this end, we have developed an algorithm to reschedule locomotives followed by related rescheduling of drivers in situations where timetables need to be adjusted. In locomotive rescheduling, many conditions need to be taken into account, such as the traction power and available area of locomotives. Above all, each locomotive must be inspected in every 72 or 96 hours depending on its type. This algorithm provides a solution that satisfies all these constraints while minimizing the number of locomotives whose schedules are changed or the number of urgent locomotive inspections to be carried out. Figure 2 illustrates a rescheduling plan in which two locomotives are delayed in their arrival at Station B. Locomotive ‘a’ replaces ‘b’ to haul the train from B to A and from A to B. Locomotives ‘c’ and ‘d’ exchange duties, but ‘d’ has an urgent inspection at Station D because there is no maintenance center in the direction of the trains that ‘d’ will subsequently pull.

The driver-rescheduling algorithm considers not only physical constraints (such as the time required for drivers to prepare for the newly assigned leg) but also practical constraints (such as sections where only specific drivers are qualified to operate trains and amounts of overtime work). Figure 3 shows an example of a driver rescheduling solution. The driver whose scheduled train is cancelled moves to his/her destination by deadheading. Our algorithm tries to minimize the number of drivers whose duties are changed, the amount of overtime work required of drivers and several other criteria depending on the settings of the associated parameters.

Algorithms for locomotives and drivers are common; both are based on network representation of problems and formulation as integer programming problems, and are solved using the column generation technique. Integer programming was considered to take a long time to reach a solution, but our temporal relaxation approach to the related problems as well as multi-thread computing, in addition to recent advances in computers and algorithms in the field, allow resolution within an acceptable amount of time. Computational experiments based on real data obtained from the highest-frequency freight train operation area in Japan showed that a three-day goal for locomotive scheduling recovery can be solved in 70 seconds using a personal computer. A rescheduling plan for over 100 drivers can be obtained in about 10 seconds.

In future studies, we plan to investigate the rescheduling of rolling stock for passenger trains in disrupted situations where the operation frequency is high and the splitting and combination of rolling stock arises often.

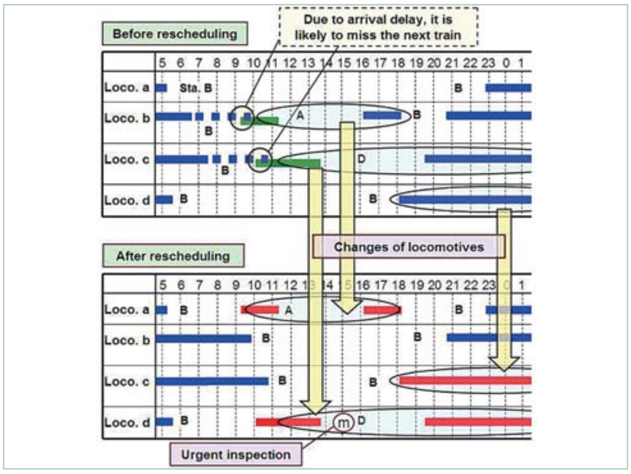

Fig. 2 A locomotive rescheduling plan

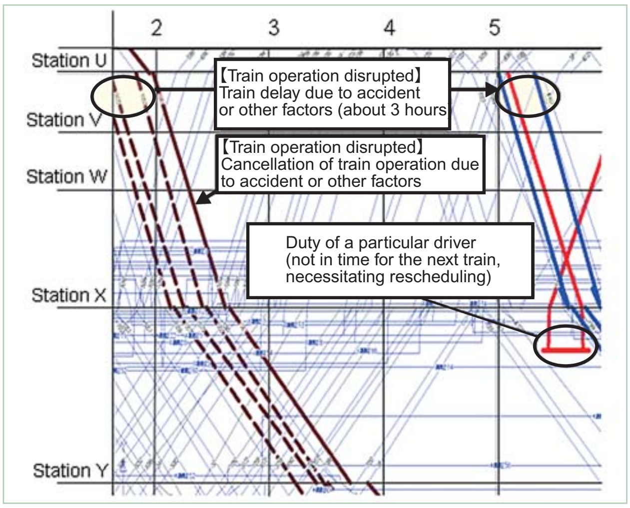

Fig. 1 A disrupted train operation situation

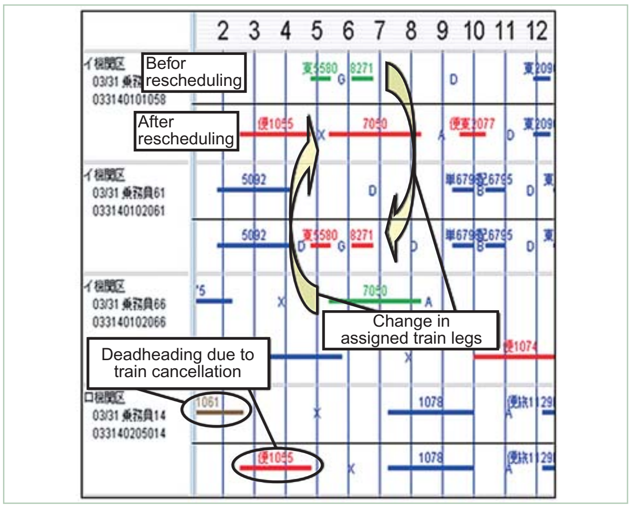

Fig. 3 A driver rescheduling plan

Extension of Grease Service Life for Induction Traction Motors for Railways

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1. Background

Since it takes significant amounts of time and effort to disassemble and inspect the traction motors of railway vehicles, there has been a need to extend the periodicity with which disassembly inspections are performed. However, now that the adoption of induction motors for traction has completely eliminated maintenance work for brushes and commutators in conventional DC motors, extending the service life of lubricating grease (which has the shortest life of all bearing components) remains an issue to be resolved.

Figure 1 shows the construction of a traction motor. To support the weight of the rotor, such motors contain cylindrical roller bearings and deep groove ball bearings, for which sealed grease is used as a lubricant.

2. Service life of grease

One way of extending the service life of this lubricant is to improve the performance of the grease itself. In recent years, grease and bearing manufacturers have developed a grease containing a synthetic material as a base oil (among other approaches), but this does not constitute a drastic solution to the problems seen with railway vehicles.

Another method of supplying additional grease without disassembling the bearing (a technique referred to as intermediate refilling) is currently applied to some railway vehicles. One limitation to be considered here is that the lack of additional greasing space around the bearings of traction motors shortens the service life of grease when it is sealed in the relevant space beyond the appropriate volume limit. To address this, it has been pointed out that the volume of grease initially sealed has been reduced in order to secure space for intermediate refilling.

Furthermore, appropriate design has been adopted for the bearing structure. It is a normally accepted view that the more grease is packed in or near the bearing, the longer the grease's service life. Since a suitable filling volume is determined for the bearing inner space (in consideration of leaving enough room to allow for the movement of the rolling elements and the cage), the injection of a much larger amount of grease is made possible by installing grease pockets (GPs) on both sides of the bearing. Figure 2 shows typical profiles of end-plate GPs. From a comparison of these, we propose the installation of outer GPs located on either side of the annular GP (types A and B, Fig. 2) - and the maintenance of a wide contact area between the annular and outer GPs as a guideline for GP configuration design with a high grease-oil supply capacity [1].

3. Improved sealing structure design and its effect

Figure 3 shows the results of a service-life comparison test for grease(*) between bearings with conventional GPs and those with GPs improved in accordance with the above guideline. In this test, we rotated full-scale bearings by simulating the actual running conditions of Shinkansen traction motors, with grease sealed to 30% of the inner space and the full capacity of GPs for both types of bearings.

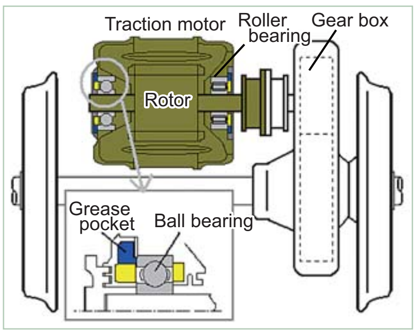

Fig. 1 Example of driving gear structure

In the case of bearings with conventional GP configurations, the ball bearings and roller bearings brought about the end of the grease's lubricating service life as indicated by the temperature rise in the inner ring after a test period equivalent to a running distance of 1,460,000 km and the motor's inability to restart after stopping at a point equivalent to a running distance of 2,630,000 km. In this judgment, we referred to the life judgment criterion in ASTM D3336. In contrast, the bearings with improved GP configurations brought about the end of the grease's service life after being tested for a period equivalent to a running distance of 3,600,000 km or more [2] (Fig. 3). These results prove that the service life of grease for bearings can be extended simply by changing the GP configuration and the volume of sealed grease; it may therefore be possible to extend the periodicity of disassembly inspection as a result.

4. Conclusion

Here we have reported on the improvement of grease sealing structures as a method of extending the maintenance periodicity of traction motors. In order to further extend the service life of grease, the development of a new lubricating system is required with consideration of improved grease performance, intermediate refilling operation and the like.

(*)The service life comparison test was conducted as a joint study with Toshiba Corporation.

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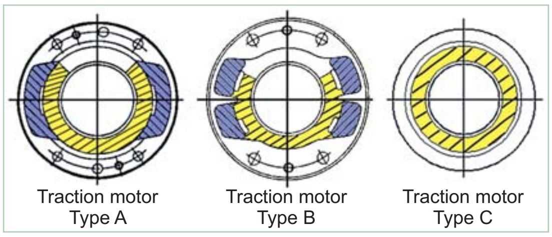

Fig. 2 Typical configurations of end-plate GPs in practical use / Grease is inserted into the annular GP (yellow) and the outer GP (blue).

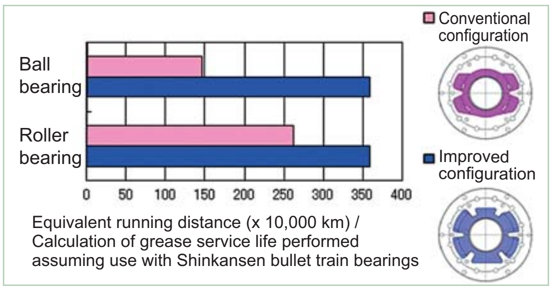

Fig. 3 Comparison of the service life of grease between bearings with conventional and improved GPs