Recent Research and Development Activities in Track Technology

Hiroo KATAOKA
Track Technology Division

Three current focal areas of research at RTRI aim to make railways more sustainable:

1. Labor-saving and automation of track maintenance in order to counter the effects of an expected fall in the number of experienced engineers and growing labor shortages, by engaging in basic and applied R&D on the utilization of information and communication technology for track maintenance.

2. Rail maintenance and management: with particular emphasis on rail corrugation, with a view to proposing fundamental countermeasures within the next few years, based on understanding the underlying mechanisms behind the problem.

3. Development of track technology for regional railways: development of lower cost track improvement methods, in order to drastically improve the LCC of regional railways within the allowable range of public economic support for railway services.

Keywords: ICT, regional railway, track maintenance

1. Introduction

The Railway Technical Research Institute (RTRI) is engaged in research and development (R&D) aimed at developing a more sustainable railway system that takes into account changes happening in society, such as population decline. Currently, there are three areas of R&D focused on this aim:

1. The development of labor-saving, automated track maintenance technology;
2. The development of rail maintenance and management technology;
3. The development of track technology for regional railways.

In the case of (1) in particular, RTRI is engaged in basic and applied R&D in response to the growing need for broader utilization of information and communication technologies (ICT) as a means to counter the falling number of experienced engineers and increasingly frequent labor shortages.

This paper outlines the recent trends in track technology related to these areas of R&D.

2. Development of labor-saving, automated track maintenance technology

2.1 Upgrading the track condition-based maintenance system utilizing ICT

Since the data analysis system for track irregularity Micro LABOCS became available for practical use in 1990, it has become possible to digitally process large scale track irregularity data. LABOCS has developed into a track

Fig. 1 Example of CBM-based track management
maintenance database system. Since then, the inertia mid-chord offset track inspection system has come into practical use, making it possible to conduct track inspection (measurement of track irregularity) using a high-frequency operation commercial vehicle. This means that the practical application of condition-based maintenance (CBM) of the railways is underway in the field of railway engineering and management. Figure 1 shows an example of recent CBM in track management, demonstrating that the automation of rapid prediction of short-term track irregularity based on highly frequent inspections, the formulation of annual maintenance plan, and the formulation of medium to long term maintenance plans covering approximately a five-year range are close to being achieved.

In order to take labor-saving developments a step further using automated track maintenance systems, RTRI is engaged in R&D to upgrade track CBM through use of ICT.

2.2 The development of a low-cost, real-time track inspection system

RTRI is developing a low cost, real-time track inspection system which can be mounted on maintenance cars as well as locomotives (Fig. 2) so CBM automation can be widely applied. This system is IoT compatible and it is able to autonomously identify its location using GNSS (Global Navigation Satellite System) and from the cross-sectional shape of the rails. It automatically sends the location information and track irregularity data to the network, which means when a vehicle equipped with the system is running, track irregularity measurements can be collected and recorded automatically.

For the time being, the aim is to develop the technology for measurement of irregularities that impact safety most, i.e. gauge, cross level, twisting and rail wear and bring it into practical service as the lowest-possible cost system. For example, one potential model of operation could be to fit the system on a few maintenance vehicles to implement CBM along sidings, in marshalling yards and along local lines, while at the same time introducing the system on specialized track inspection vehicles given operational priority on key main lines.

2.3 S-type solid-bed track with resilient sleepers

One of the recent successes in the area of track structure development is the S-type solid-bed track with resilient sleepers (STR) (Fig. 3). The directly fastened tracks are used primarily for Shinkansen lines and in urban areas, since they are a low-maintenance structure. For environmental reasons, elastic pads are placed under the directly fastened sleepers. The S-type STR design simplifies the structure and costs significantly less than the conventional D-type STR. By revising the shape of the sleeper, the track is able to support lateral load with what are called shear keys on the side of the sleepers, removing the need to pour concrete-bed track shoulders. One of the main features of this design is the use of short-fiber-reinforced concrete, which means that rebars are no longer required, greatly improving workability. This structure is currently being laid on commercial lines.

3. Technological development concerning rail maintenance and management

3.1 Recent issues concerning rail maintenance and management

Rails are central to any railway, since they support vehicles directly. Significant resources go into managing rail damage and wear, and for this reason, there is a demand for reduced cost technology that does not compromise safety. Recent issues in maintaining and managing rails include:

1. Clarification of the mechanisms that cause rail corrugation and development of preventive measures;
2. Improving reliability and simplifying the technical aspects of rail welding;
3. Prediction of rail crack growth;
4. Broadening the application of rail crack repair methods.

(1) to (3) have been researched for many years, but it is only recently, due to improvements in experimentation methods and analytical technologies that quantitative numerical simulations based on fundamental physical characteristics are becoming possible. In particular, there is a concentrated effort to make recommendations for countermeasures against rail corrugation (Fig. 4) based on its generating mechanism.
3.2 Rail crack growth

In the case of rails, research has been carried out from various angles, such as examining the type and quality of materials and improvement of inspection methods which would ultimately lead to labor-saving solutions. However, since rails carry the heavy load of wheels directly, it is difficult to eliminate surface damage to rails. For this reason, it is important to understand the speed of crack growth to make inspections and solutions more efficient. While it is known that residual stress in the rail head contributes to the growth rate of transverse cracks on the head, recent research using the Modified Internal Residual Stress (MIRS) method has made it possible to investigate residual stress in detail and capture the changes in the distribution of residual stress caused by the weight of trains. We have developed a head crack growth analysis tool that takes the indoor test results into consideration and going in depth to able to estimate the development speed according to the local conditions (Fig. 5).

3.3 Clarification of mechanisms leading to rail corrugation

The purpose of investigations into rail wear causing corrugation include:

1. Understanding the current reality of corrugation through highly accurate on-site measurements and plastic flow analysis of the rail at contact surface with the wheel;
2. Estimation of the deciding factor in the wavelength of the rail corrugation using a wheel/track interaction model (Fig. 6);
3. Simulation of periodic wheel load variation through vehicle running analysis that uses multibody dynamics;
4. Investigation through running experiments on a test line to reproduce the conditions that lead to corrugation.

Through these four approaches, clarification was obtained of the mechanisms generating rail corrugation damage on curved inner rails, curved outer rails, and straight rails.

Previous tests examined vibration systems and vibration modes of vehicles and tracks that caused periodic wheel load variation that defines the wavelength of rail corrugation. As a result, it was confirmed that each type of rail - curved inner rail, curved outer rail, and straight rails - has a different vibration system that causes corrugation, and the cycle of the periodic wheel load variation that occurs in each vibration system is mostly consistent with the wavelength of rail corrugation measured locally [2]. In the next step of this research, more in-depth vehicle running simulations will be conducted using MBD (multibody dynamics) along with driving tests on a test line, to investigate the mechanisms that cause corrugation and propose a development plan to produce decisive countermeasures.

4. Track technology development for regional railways

4.1 Cost reduction of track maintenance in regional railways

Below are the two main possible ways to reduce the cost of track maintenance:

1. Radically reducing LCC (life-cycle costs) through structural improvement.
2. Reducing the cost of elemental technologies of maintenance to preserve their current state.

On many regional railways, deterioration is so severe that the best alternative would be to radically improve LCC by focusing on (1) above, but solutions are difficult to apply on routes that are less profitable, unless there is some financial support. For RTRI, it is essential to fundamentally improve the LCC of regional railways within the limits of financial support available for public services, so its aim is to develop and propose methods that can improve track structures at much lower costs.

Also, to reduce safety related costs on regional railways, even a little, low-cost basic technologies are being developed for track maintenance under (2), with a view to introducing new measures into practice as soon as possible. For example, the introduction of the new "repair method
4.2 Method to recover functionality of ballasted track with a high-ratio of fine particles through granulation

When ballast deteriorates, particles resulting from crushed and worn ballast and soil penetrate from the outside increasing ratio of fine particles in the ballast. Since tamping maintenance is not very effective against this kind of ballast containing fine-particles, it is preferable to replace the ballast. However, for local, low-profit lines, as is the case with regional railways, this is not economically feasible. RTRI, therefore developed a repair method using a polymer which was applied in practice, and the results obtained so far are generally positive. In some areas however, the method was not fully satisfactory.

A low-cost production method is therefore now being developed that can produce positive results even in harsher conditions. This method consists in restoring the original functionality of the ballast by turning the fine particles inside the deteriorated part into particles of a certain size (a process called granulating) using a hardening material such as cement milk (Fig. 8). While the effect of this method has already been confirmed with loading tests and field tests, it is still necessary to solve some issues, such as defining the correct dose of hardening material for different ballast conditions and devising an efficient construction method, before it can rolled out.

4.3 Development of low-cost, Continuous Welded rail tracks

As one of the pillars of track structure improvement for regional railways, RTRI is developing low-cost, Continuous Welded rail (CWR) tracks. In Japan, there are many narrow-gage lines, and in structures that have ballast containing fine-particles with wooden sleepers, which are common in regional railways, the ballast generally has low lateral resistance, and many are still jointed rail sections with fishplate. Most cases of ballast track deterioration and track irregularity are concentrated in the rail joints. Therefore, if CWR can be introduced to regional railways with low tonnage, it may eliminate most of the track irregularities and possibly reduce a large part of track maintenance work.

Four elemental technologies were therefore developed, as described below, which are necessary to implement low-cost, CWR (Fig. 9):

1. Low-cost lateral resistance increase method for ballasts containing fine-particles (basically eliminating the need for ballast replacement)
2. Securing rail creep resistance in partial PC sleepers (reducing required number of PC sleepers)
3. Welding method for rails with small sectional areas (e.g., 40 kgN) (minimizing rail replacement)
4. Low-cost expansion joints structure (cutting out the need for expansion joints and reducing number of welded points)

(1) in particular, is a method that stiffens the ballast.
shoulder with cement and increases lateral ballast resistance, the most critical technique to guarantee a safe CWR track with a minimum number of PC sleepers. After basic experiments and simulations, the performance of the countermeasure was verified with a full scale track model buckling test (Fig. 10), which confirmed its effectiveness.

5. Conclusion

To centralize the management of maintenance information such as tracks, electric power, signals, and structures, RTRI is currently building a framework for different disciplines to share location information and is also developing a global management system of maintenance information based on LABOCS. Innovative work in the field of track technology will therefore continue, tackling the subject from various angles.

References

[1] Y. Tsubokawa, T. Ishikawa: “Development of a Dynamic Track Measuring Device for Gauge and Twist to Reduce Derailment Accidents,” *WIT Transactions on The Built Environment*, Vol.181, pp.253-262, 2018.

[2] H. Tanaka, K. Kajihara, M. Aboshi: “Classifying the Generation Form of Rail Corrugation,” *World Congress Railway Research 2019*, 2019.

[3] T. Nakamura, K. Muramoto, Y. Yabunaka, K. Nomura: “Development of repair method using polymer for ballasted tracks with a high-mixture ratio of fine particles,” *15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering*, 2015.

Author

Hiroo KATAOKA
Director, Head of Track Technology Division
Research Areas: Track Components and Structure