Recent Research and Development Results and Outlook for Track Technology

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RTRI’s new Master plan began this year in 2020. In this plan, one of the directions set for research and development is how to use ICT to save labor in track maintenance. This report describes research results from the field of track technology achieved during the previous five-year master plan, and introduces RTRI’s research policy for the new Master plan. Research results include, for example, an integrated data management system for railway infrastructure, the development of a system to support track monitoring from onboard trains, and a method for detecting loose sleeper on ballasted track. In future, we aim to use digital technology to facilitate track inspections and improve prediction methods.

Keywords: digital technology, labor saving, inspection, condition based maintenance

1. Introduction

At the beginning of FY2020, RTRI started its new 5-year Master Plan ‘RESEARCH 2025’. The railway industry is facing a dramatic change in the operating environment as facilities and equipment age and Japan’s birthrate continues to decline while its population grows old, exacerbating an existing labor shortage. Against this background, substantial labor saving, automation and cost reductions need to be achieved to make the railways sustainable.

Track maintenance presents a number of particularly challenging issues, such as deterioration of the extensive network of tracks and the need to save manpower. Aware of these issues, railway operators have been striving to improve productivity. To help develop more sustainable track systems, RTRI has been working to develop solutions based on the advancing digital technology that contribute to cost reduction, labor saving and improving safety.

This paper presents an overview of related research and development projects undertaken so far, and attempts to foresee R&D trends for the coming years.

2. Track technology development in RESEARCH 2020

The previous Master Plan RESEARCH 2020, which spanned the period from FY2015 through to FY2019, set out the following R&D Objectives: (1) Improvement of Safety, (2) Cost Reduction, (3) Improvement of Convenience, (4) Harmony with the Environment - - and covered a wide range of research and development from "Basic research for railways" to "Development of practical technologies" to "R&D for the future of railways." In terms of track technology, the research and development projects shown in Table 1 were undertaken and the results have been used in practical applications and for a range of different types of evaluation.

Some of the key results are outlined below.

(1) Waveform matching method and location/prediction method for rapidly-growing track irregularity for high-frequency track measurement

Currently, high-frequency track measurements carried out by commercial vehicles using the inertial mid-chord offset method is being introduced, helping the development of ‘condition-based maintenance’ (CBM) of tracks. Track irregularity waveform matching using the cross-correlation method is a technique for determining similarities between sections of waveforms, which have been measured at dif-

| Category | Item |
|----------|------|
| Maintenance using digital technologies | Improvement in rail detection method for track measuring device with the inertial mid-chord offset method |
| | Waveform matching method for high-frequency track measurement and its application to condition-based maintenance |
| | Mid- and long-term track maintenance planning support system |
| | Risk based maintenance method |
| | Track patrol support system using image analysis |
| | Low-cost dynamic track gauge and twist measuring system |
| Cost reduction / Labor saving | Method for repairing damaged rail heads |
| | Method for protecting rails against corrosion |
| | Performance evaluation method for rail fastening system |
| | Elastic support structure of expansion Joint |
| | Solid-bed track equipped with resilient sleepers using shear-keys |
| | Method for determining level of deterioration in CA mortar of slab track |
| | Portable FWD for measuring track support stiffness |
| | Low-cost method to recover functionality of ballast track |
| | Low-cost continuous welded rail track structure |
| Development of phenomena analysis/simulation technology | Rail corrugation growth mechanism |
| | Rail crack propagation and rail lifespan evaluation |
| | Method for determining and predicting ballast deterioration |
| | Method for simulating vehicle behavior when running through turnouts |
| | Safety analysis of a vehicle running on a broken rail |
ferent times and are then matched (Fig. 1). This allows efficient processing of high-frequency track measurement data and subsequent monitoring to detect changes in the processed data.

The technique is already being used, for example, for predicting track irregularity and related ride comfort management and locating rapidly-growing track irregularity. The technique is the basis for track CBM as it also enables matching of different types of waveforms, allowing for these data to be analyzed together.

(2) Risk based maintenance

Risk based maintenance uses track maintenance standards and prioritizes sections for maintenance based on derailment risk. An associated risk detection system has also been developed which processes images captured from the front of the train, using the image processing technology described later in this paper, and automatically maps and displays risk areas along a track. This maintenance method offers prioritized maintenance of high-risk locations, helping to improve section-wide safety.

(3) Rail head damage repair method

This repair method involves the partial cutting and removal of damaged rail heads, with defects such as individual rail squats which are common on commercial lines, and then repaired by means of alumino-thermic welding. This method eliminates conventional processes such as restressing after rail replacement and welding. Rail straightening machines, such as the one shown in Fig. 2, are being improved so that the method can be extended to heat-treated rails and ballastless track.

(4) Solid-bed track equipped with resilient sleepers using shear-keys

A modified version of the detachable track with resilient sleepers, the solid-bed track equipped with resilient sleepers resists lateral load with a shear-key on each side of the sleeper, making it possible to narrow the concrete bed. The use of short-fiber-reinforced concrete eliminates the need for reinforcing bars, substantially cutting installation time. A version using a wire spring clip fastening system is being developed to expand the scope of application.

(5) Low-cost ballast restoration method

The aging deterioration mechanism of ballast is one of many subjects being increasingly studied in recent years. Through these efforts, a range of results have been gained on how the content rate of fine particles affects track subsidence. Stabilization of deteriorating ballast including fine particles using biodegradable polymers is a low-cost restoration method for such ballast and has been used in practical applications. A granulation technique has also been developed, and is still being improved to reduce related costs, to prevent deterioration to the point where mud pumping occurs.

Furthermore, a continuous welded rail track structure has been developed for regional railways that stabilizes ballast shoulders using cement to maintain lateral resistance (Fig. 3).

(6) Improvement in simulation technology

Efforts are also being made to develop vehicle running simulation technology. Using the developed dynamic explicit vehicle running simulation tool, it is possible to simulate a vehicle running through turnouts or running over gaps in broken rails. The tool has been used for various design and evaluation purposes. In addition, vehicle running analysis using MBD (multibody dynamics) has been used in various technical evaluations and studies.

3. Recent technological developments

Recent research and development relating to labor-saving track structures are as follows:

3.1 Efforts to build a centralized management system for fixed railway installations

Currently, data is collected by different divisions separately, and sometimes in isolated fashion within a same division, which means that data are often handled in isolation. Centralizing the management of all these data is
expected to contribute greatly to better maintenance of the railway infrastructure going forward. At RTRI, efforts are underway to build a centralized, cross-divisional data management system that will be based on LABOCS, which has evolved from a track irregularity data analysis tool into a track maintenance data base.

To achieve this, the management of shared positional information is important. While key positional data is different from one division to another, positional information when handled as distance data can be managed on LABOCS. In addition, latitudinal and longitudinal information of the data gathered using inspection tools can be converted into distances. Figure 4 shows an example of centralized management system charts. Images of a selected track position can be displayed for diagnosis and, if required, planning of repair. Various other data can also be centrally analyzed.

Fig. 4 Example of screens on the centralized management system

3.2 Track Patrol support system using image analysis

The track Patrol support system consists of two stereo cameras installed at the front of the train to capture images and monitoring technology for clearance gauge obstacles and other trackside conditions, and relies on the application of (1) camera position and posture estimation, or localization technology, (2) multiple-viewpoint 3-D imaging technology and (3) difference detection technology.

The localization technology is designed to select features and calculate the cameras’ positions and postures, is capable of estimating running routes even in sections with poor GNSS signal reception and helps improve the accuracy of 3-D imaging. It enables the detection of obstacles by setting up a framed space in a multiple-viewpoint 3-D space (Fig. 5).

It also is capable of associating two different images captured at different times and identifying any difference between them. As a result, changes in track, if any, can be flagged.

These technologies are expected to replace visual inspections normally carried out by crews on monitoring trains for clearance gauge obstacles and other trackside conditions, which should save labor for Patrol work.

Future plans include improvement in the system’s accuracy and further studies on how 3-D imaging data can be utilized.

3.3 Loose sleeper detection method

Loose sleepers on the ballasted track do not just compromise ride comfort but present various other issues. While loose sleeper detection methods using 5 m-chord track irregularity and RFWD (portable track stiffness measurement device) have been proposed in the past, a new quantitative analysis method based on restored track irregularity has been developed.

Using LABOCS, restored track irregularity can be calculated from measured track irregularity. Track irregularity under unloaded condition can be estimated by putting the restored track irregularity originally measured under loaded condition through own weight analysis. The difference between the track irregularity under unloaded condition and that under loaded condition is the loose sleeper gap (Fig. 6).

The method has been verified using data collected on commercial lines. One of the key features of the system is that the gap and distribution of loose sleepers can be quantitatively analyzed. For that reason, the system can be used for studying track redundancy, for improv-
4. Research and development under RESEARCH 2025

With the underlying factors in mind that were mentioned at the beginning of this paper, RESEARCH 2025 aims to drive research and development efforts in the following basic direction:
(1) Enhancing safety with an emphasis on improving resilience against natural disasters
(2) Developing innovative railway systems based on digital technologies
(3) Creating high-quality results by taking advantage of our collective strength

The track technology division will conduct a wide range of studies, including basic and practical studies, focusing on the utilization of data from on-board measurements, the development of sensing technology and the advancement in prediction methods.

4.1 Maintenance methods using digital technologies

Efforts will continue to better understand track structure deterioration mechanisms, such as rail crack growth speed and ballast deterioration. These phenomena will be quantified through more accurate simulation. As for inspection, currently the following systems and methods are being developed for practical application: an on-board rail breakage detection system, a dynamic track measuring device for gauge and twist and a method for determining the degree of ballast deterioration. Along with this work, another target will be the automation of various inspections. Prediction technology will be improved through the comprehension of the deterioration phenomena mentioned above and our entire inspection system will be restructured.

This will be a shared system for both track and structures. Simulation and on-board measurement data will be utilized not just for tracks but for grasping any deformation in structures.

Turnouts are structural members that require a great amount of labor for adjustment and inspection. Normally, tongue rails are supported by one or two switch rods laterally and the heel, requiring a great amount of labor for inspection and adjustment to be kept in the proper shape. For that reason, switch movements integrated in a sleeper shown in Fig. 8 and a turnout structure incorporating the sleeper-integrated switch movements will be developed. Switch movements with control and monitoring functions will be installed at plural locations in a point to realize an intelligent turnout with synchronous, multi-point control for labor-saving CBM.
5. Conclusion

This paper presented past, present and future examples of research and development in the field of track technology and described the R&D outlook for coming years. Practical subjects such as low-cost repair methods and low maintenance tracks will also be included in the scope of ongoing work.

On international standardization activities related to tracks, RTRI has been involved in deliberations, with RTRI’s Railway International Standards Center as the secretariat, for the standardization of various proposals, for example ballastless track.

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