Latest Research and Development in Materials Technology

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Since the materials for the railway system are required to maintain the designated performance over a predetermined period of time, it is necessary to deal well with the changes over time of the used materials. On the basis of this background, our current researches mainly consist of long-time service life materials such as concrete or steel structures, and friction members such as rail, wheel, bearing, brake shoe, contact wire, pantograph contact strip. We are also developing new materials or new technologies represented by superconducting power feeding cable. This paper shows the outline of our recent research and development activities in materials technology.

Key words: materials for railway applications, clarification of phenomena, evaluation methods, new materials, development of materials

1. Introduction

Railways are essentially a land-based system for the carriage of people and goods, and this system relies on a wide range of materials to be able to function. “These “materials,” (or ‘tangible elements’) along with the rapidly evolving world of “information” (‘intangible’ elements) work together under the control of human beings to form the foundation to railway technology (Fig. 1). Each type of material used therefore, is expected to meet a certain required level of performance for a set period of time in order to enable safe and undisrupted train operation.

What is important here is that materials must not only “meet a certain required level of performance” but do so “for a set period of time.” Otherwise, the equipment where these materials are used cannot function properly. Underperforming materials may not be a major issue if they are easily replaceable and thus have minimal impact on train operation and other areas. However, poor performance can lead to failures and accidents if the materials are used in critical components.

This suggests that proper management of the deterioration of ageing materials for safe and undisrupted operation of a railway system, is extremely important. A great deal of past and current research and development projects have therefore naturally tackled and are still focusing on this fundamental issue.

Materials innovation is one way to help advance the railway system because new materials are a means to achieve step changes in the system. As such, RTRI has been actively pursuing the development of new materials and technologies.

This paper presents an overview of RTRI’s research and development efforts in the materials division including the background and its outlook for the future.

2. Characteristics of materials for railway applications

Managing the deterioration of materials because of ageing in the railways as mentioned in Section 1, is important especially important in relation to:

1) Long-term outdoor exposure to the elements
2) Frictional sliding materials

Whilst these two aspects have been prioritized by RTRI’s materials division [1], another area has been highlighted as being essential for advancing the railway system as a whole:

3) Development of new materials and technologies to achieve step change railway system progress.

These areas will be discussed below in the order they are mentioned above.

2.1 Long-term outdoor exposure to the elements

Civil structures such as those made of concrete or steel are expected to last over 100 years in service. In fact, an increasing number of civil structures have been in service for over 100 years.

Structures which cannot deliver the expected service life need to be replaced at the appropriate time, whilst for those that can be maintained at an acceptable cost, it makes sense to harness all available maintenance knowledge and technology to keep them in service. Vehicles on the other hand are not expected to remain in service as long as civil structures, but overall still have longer service life than motor vehicles.

Materials are generally more heavily impacted when used outdoors than when used indoors, because of temperature changes, solar irradiation and rain water. This can often lead to the deterioration of materials. In order to ensure that the ageing of materials is properly managed it is necessary to understand the impact of these outdoor conditions, to be able to control their influence accordingly.

2.2 Frictional sliding materials

Frictional sliding materials are essential for the railway system which has land-based vehicles running on tracks involving “movable parts in contact with fixed parts.” This “moving parts in contact with fixed parts” relationship is present across numerous areas in the
system, for example, wheels and rails, contact wires and pantographs, and axles and bearings. This harsh environment means that the materials are under constant frictional sliding and are therefore more prone to deterioration with ageing, which affects their performance.

2.3 Shifting to new systems, enabled by the development of new materials and technologies

The aims of achieving step-change improvements in the railway system include the prevention of performance loss of materials, and replacing materials prone to deterioration with other more resilient materials, in order to improve accident and failure prevention, as well as reduce the cost and need for maintenance.

2.4 R&D approach

To properly manage deterioration of materials through ageing, it is essential to clarify the mechanisms underlying their deterioration, and develop methods for evaluating the condition of materials as well as design suitable countermeasures, as shown in Fig. 2.

Possible ways to achieve this, include site investigations, experiments and simulations. When combined, these methods can help gain clearer insight into the various factors at play in the field, and in turn can contribute to developing effective countermeasures. As such, recent progress in simulation techniques will be actively employed, along with site investigations and experiments, in order to optimize the synergy between these different exploratory approaches.

3. Major research and development projects currently underway

Figure 3 shows some of the research and development projects in the materials field that are currently underway at RTRI.

They cover a wide range of fields, from vehicles, civil structures and tracks to ground facilities such as those related to power supply, signaling and communications. The projects presented here are grouped by phase of investigation, namely, clarification of deterioration mechanisms, and development of evaluation methods and countermeasures, with each shown in its current phase of development, in Fig. 3. Projects which are currently investigating deterioration mechanisms will then either move on to, or conduct simultaneously, work to design evaluation methods and countermeasures. Ultimately, it is hoped that the findings can be adopted by railway operators.

3.1 Clarification of deterioration mechanisms

Clarification of deterioration mechanisms is essential to scientifically establish actual phenomena occurring in the field and properly manage the ageing process which causes the deterioration of materials. It is also extremely important for the continued growth of...
railways.

Numerous studies have been conducted on deterioration mechanisms, making great contributions to daily railway operations. There are still phenomena occurring in the field however, that cannot be explained using existing concepts. Therefore, these hitherto unexplained phenomena are being studied at RTRI from angles which go beyond conventional theories.

For example, it is becoming evident that carbonation-induced steel corrosion, an issue often and typically raised for reinforced concrete structures, is more heavily influenced by the action of water than the carbonation of concrete [2]. Based on these findings, studies are underway on water infiltration into concrete and other related areas, with the most recent research focusing on the impact of repair materials on the behavior of water and other subjects.

Another example is delayed ettringite formation (Fig. 4), a cause of concrete expansion and resultant cracking. There is a possibility that the combination of delayed ettringite formation and another phenomenon called alkali-silica reaction promotes the expansion of concrete, inducing the cracking of existing structures. This was investigated in the referenced study [3]. While many studies have previously investigated delayed ettringite formation using conditions favorable to the formation, the referenced study focused on the conditions for possible formation commonly found in railway structures.

With flange climb derailment which can typically occur when vehicles are running through turnouts and sharp curves, efforts are underway to develop methods for clarifying wheel/rail frictional behavior in the initial stages following wheel grinding to determine the cause of flange climb derailment (Fig. 5) [4]. While wheel and rail surfaces both appear nearly smooth, up close they have minute dents and bumps. In fact, they are in contact with each other where those protuberances meet. The efforts specifically aim to clarify the mechanism underlying increases in friction coefficient on the contact surfaces, by visualizing the state of the contact (contact stiffness) using ultrasonic waves.

3.2 Development of evaluation methods

Work is being carried out to develop various evaluation methods, including methods to assess the quality of concrete, to monitor the condition of engines and other components through lubricant analysis and rolling contact fatigue layers in rails. This paper briefly presents studies utilizing simulation techniques.

Materials have thus far been developed primarily through understanding phenomena which occur in the field and through experiments. Combining these methods and simulation techniques however, is more likely to lead to discovering better materials. Therefore, work has been carried out to develop materials simulation techniques [5]. While those techniques are being studied in a range of organizations, RTRI projects are typically organized according to a specific approach. For example, with composites, projects aim to evaluate the macroscopic, practical characteristics of materials, employing methods that use Young’s modulus, for example, and thermal conductivity through modeling microscopic enough to achieve that. Currently, efforts are being made to develop a method for estimating the physical properties of pantograph contact strips through homogenization analysis using X-ray computed tomography image-based modeling (Fig. 6).

With noise simulation considering in the characteristics of sound-absorption materials, a simulation method has been developed for evaluating sound-absorbing materials often attached on the side of noise barriers and polycarbonate boards often used as the extra noise barriers to increase their height, for their sound insulation and absorption performances.

The simulation method will be used to develop noise barriers with even higher sound insulation performance, such as by trying to find combinations of materials that possess a higher sound-absorbing effect (Fig. 7).

3.3 Development of countermeasures

While clarification of deterioration mechanisms and development of evaluation methods help improve daily operations in the field, the expertise gained from those efforts can be harnessed to develop countermeasures to directly achieve results.

On electric railcars and electric locomotives, driving force generated by the traction motor is transmitted via a gear unit to the axles and wheels. Seizure of the bearings in the gear unit can adversely affect the running of the vehicles. To prevent such a damage, a rotation test equipment of an actual gear unit was fabricated (Fig. 8) to study how reduction in clearance (endplay) around the pinion, a cause of seizure, can effect the temperature and vibration of the gear unit [6] while at the same time a new design is being developed that eliminates the need for this clearance management.

Other ongoing RTRI projects include the development of pan-
to graph contact strips that reduce contact wire wear, the development of gear oil for Shinkansen cars operated in cold climates, the development of wheel/rail adhesion improvement methods and the development of vehicle materials with even higher incombustibility. One of great contributions that the materials field can offer relates to a potential shift to new systems, or an innovation, through the development of new materials etc. For example, efforts are underway to develop feeders made of high temperature superconducting materials that are capable of transmitting power without voltage drops.

4. Conclusion

Various kinds of materials are used for railway applications. Those materials deteriorate over time, which may negatively impact safety, disrupt operations or otherwise require labor intensive maintenance. It is therefore important for railways to effectively manage deterioration from ageing of materials. Furthermore, the development of new materials and technologies is a key to unlocking step-change improvements in railway systems. RTRI will therefore pursue its work and development of materials for railway applications to help further improve safety, save labor, cut costs and protect the environment in a rapidly changing business environment.

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