Recent Research and Development Activities in Materials Technology

Hiroshi UEDA
Materials Technology Division

Since railways began, materials technology for railways has progressed in line with railway technology development. Current research focuses mainly on materials with a long serviceable life, such as concrete or steel structures, and parts subject to friction such as rails, wheels, bearings, brake shoes, contact wires and pantograph contact strips. New materials or technologies are also being developed, among which superconducting power feeding cables are a representative example. This paper outlines recent research and development in materials technology.

Keywords: railway materials, characterizing phenomena, evaluation methods, new materials, material development

1. Introduction

In the 112 years since the founding of the Railway Technical Research Institute, progress in railway material research and development has kept pace with development of the railways themselves. It is well known that a wide range of materials is used for railways, and it would be impossible to research each type of material individually. Through necessity therefore, research has focused on those that influence railway operations most, and whose characteristics can be examined in laboratories, with a particular focus on matters relating to how materials change over time. More specifically, this refers to research which elucidates and devises countermeasures against the causes of material deterioration and damage. This paper reviews the research and development conducted by RTRI in the field of materials and introduces the major research and development outcomes of recent years.

2. Recent major research and development results

The major findings from RTRI are published every year on its website under the heading "major result of research and development" [1]. Figure 1 shows the major research and development subjects investigated by the materials technology research division since 2010. Many subjects relate to vehicles, and civil engineering structures / tracks.

3. Major research and development currently underway

3.1 Major research and development subjects

Research and development issues in material disciplines have evolved over the years, but issues that are currently under investigation include:

- Increasing the service life of railway sleepers
- Development of high-strength concrete for railway structures
- Improving the lightweight properties of railway vehicles
- Development of new materials for railway track structures
- Research on the impact of climate change on railway materials

Fig. 1   Major research and development results in materials (since 2010)
essential for railway system operation and which the Railway Technical Research Institute has prioritized are:

(a) Dealing with long-term outdoor use
(b) Dealing with sliding materials

It is natural for materials to exhibit the required performance at first, but this research focuses on how “materials change over time.” Effectively dealing with material changes over time such as abrasion and corrosion are exceedingly important for increasing railway safety and minimizing maintenance.

Additionally, a necessary issue for developing new railway systems is:

(c) System changes from the development of new materials / technologies.

This includes not only replacing existing materials with new ones, but also revolutionizes railway systems by developing and introducing new materials / technologies that have not yet been applied, such as superconducting feeder cables, which will be discussed later.

Major research and development issues recently implemented are shown in Fig. 2. These issues broadly fall into one of two categories: elucidating phenomena, such as elucidating deterioration mechanisms; and, development and introduction of new materials / technologies, such as the development of new countermeasure technologies.

Issues that focus on elucidating deterioration mechanisms are often conducted in conjunction with the development of countermeasure technologies in order to apply the results in practice.

3.2 Dealing with long-term outdoor use

With regards to long-term outdoor use, for example, many structures over 100 years old are used as civil engineering structures. There are various causes behind concrete structure deterioration, of which water is one [2]. Meanwhile, water is also needed for concrete structures, so an effective relationship between the two is important for the sound maintenance of concrete structures. Water permeability of concrete can vary widely even with identical composition based on curing method, so the establishment of concrete surface layer quality assessments and particularly evaluation methods on water permeability, are needed. RTRI has proposed a method involving a spray test as a simple means to evaluate concrete surface layer quality (Fig. 3) [3]. Research and development on this method was carried out because of its significant influence on painting methods and durability of steel structures.

3.3 Dealing with sliding materials

Railways are systems where vehicles operate on land to carry passengers or freight, so there are necessarily moving and non-moving parts, and assuring the soundness of boundary components is important from a material standpoint. These types of boundaries include: the rail and the wheel, axle and the main electric motor shaft, the gear axle and bearing components, or contact wire and the pantograph slider. The prevention of cracks or minimization of abrasion of both the materials in contact are important issues. For example, rail abrasion cannot increase significantly when a wheel with minimal abrasion is developed. Research and development in this field requires both understanding the subject material and having a wide per-
spective on the directions of material development. Furthermore, different material characteristics are sometimes demanded depending on the section. For example, lubrication in the flange part is needed in order to reduce flange abrasion in the wheel, but adhesiveness is needed on the wheel tread in order to prevent slipping and sliding. With this in mind, we developed a wheel tread friction material what reduces abrasion in the wheel flange in order to address both these material needs (Fig. 4). The material integrated a thickening abrasive on the tread part and an individual lubricant on the flange part, whose contrasting performance fulfills this need.

In order to develop preventive measures for fretting wear of axle bearings, elucidation of the fretting wear phenomena caused by repeated slight relative slips between the inner ring and the backing ring, and investigation of the preventive measures have been conducted (Fig. 5) [4]. Many railway materials are required to deal with vibration, but there are influences from these types of small-scale vibrations in addition to larger vibrations, and research and development on these types of micro-vibrations has been carried out.

3.4 Initiatives for development of new materials / technologies

System changes due to the development of new materials and technologies are major contributions to the research and development in the material disciplines, and are connected to major innovations. High-temperature superconducting materials have been used for railway feeder cables to develop superconducting feeder cables that are capable of electricity supply without losing voltage. Recently, with the cooperation of the Bureau of Transportation Tokyo Metropolitan Government and the Tokyo Metro, system isolation tests and conduction tests were carried out on actual vehicles while in operation with a DC 600 V electric supply as part of applied trials for practical use [5]. System isolation tests confirmed that vehicles can continue to operate with an electric supply based on existing feeder cables even in cases where the system was isolated from the existing electric circuit while being connected to it in parallel. Furthermore, with the cooperation of the East Japan Railway Company, we linked our system to the feeder circuit of the Chuo Line (DC 1500 V), and implemented conduction tests and system isolation tests with actual trains while in operation (Fig. 6) [6].

3.5 Railway materials and technologies in response to computerization

The application of IoT, big data, and AI has been anticipated with the recent development of information transmission technologies, and its active use in railway technologies is in high demand. An example of material technologies playing a role in computerization is for example the development of sensing materials. Technologies are currently being developed that can detect loads on axle springs by incorporating load-detecting sensors that use piezoelectric materials (lead zirconate titanate, PZT) in the inner parts of rubber set up in the axle springs of vehicles (Fig. 7) [7].

4. Conclusions

A wide range of diverse materials are used for railway materials. Defects in even just one of these materials can result in safety / stability problems. Each material is used in a sound manner by its precise production from manufacturers, precise maintenance from railway operators, and the efforts of many associates. In future, we would like to continue research and development of railway materials while further increasing safety, reducing manual labor, reducing costs, responding to environmental needs, and keeping in mind the business environment which is sure to change in the future.
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Fig. 6 Superconducting electrical system set up at the Hino Civil Engineering Testing Station

Fig. 7 Status of buried axle spring rubber and sensor

Author

Hiroshi UEDA
Director, Head of Materials Technology Division
Research Areas: Durability of Concrete and Related Materials