Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

Foreword

Mitsutoshi INAMI

By Mitsutoshi INAMI, General Manager, Planning Division

The Joetsu Shinkansen, which was disrupted by the Niigata Chuetsu Earthquake, restarted services on December 28, 2004, and was put back into normal operation for the first time in 66 days. Despite the fact that the earthquake caused derailment of a train on the line, there was not a single casualty. Some say that was "lucky." I do not think that this was merely good luck. Forty years have passed since the first Shinkansen was put into operation. Since then, Japanese railway engineers have made continued efforts to improve the earthquake-resistance of the Shinkansen system, while learning lessons from, say, the great Hanshin-Awaji Earthquake in 1995. I feel, therefore, that in the Niigata Chuetsu earthquake, fortune favored these efforts.

However, there are still many things to do to make the Shinkansen system much more resistant to earthquakes. RTRI has been striving to clarify the mechanisms of train derailment during an earthquake. At present, a significant amount of resources is being poured into the research on this particular subject. As increasing quantities of research results are accumulated, we anticipate that new technology developments will be implemented for improving the earthquake-resistance of the Shinkansen system, including vehicle/track structures which reduce the possibility of derailment, inventions to minimize the damage to passengers in case of derailment, wayside structures having better resistance to earthquakes, and more sophisticated early warning systems.

Starting in April 2005, RTRI will launch research activities based on its new master plan—Research 2005. For the coming five years, RTRI will implement R&D in accordance with this master plan. (For a detailed description of the master plan, see the relevant article in this volume.)

Since 1990, RTRI has implemented technology development for Maglev on the Yamanashi test line. This stage of project was finalized in March 2005. The Maglev Practical Technology Evaluation Committee of the Ministry of Land, Infrastructure and Transport has judged that "The key technologies for practical application of Maglev have now been established." In Research 2005, therefore, RTRI is to focus on applying its accumulated Maglev technologies to conventional railways, instead of extensive Maglev technology development.

Research 2005 has been formulated based on predicted changes in the Japanese railways and social structure during the next 5 to 10 years. The major changes predicted include: (1) a continually declining birthrate and increasingly aged society in Japan, (2) growing national awareness of the global environment and (3) rapid progress in IT.

With the recognition of the above trends, RTRI intends to create new technologies for the future of railways by implementing R&D activities more energetically than ever before. These include new railway management technologies for saving labor, railway services that are convenient and comfortable even to the elderly, fuel cell vehicles, technology for saving energy, and maintenance technology applying remote monitoring and satellite communication.

Mr. Mitsutoshi INAMI

From Editor
Toru MIYAUCHI: Assistant Manager, International Affairs, Information and International Affairs Division
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Outline of the New Master Plan (RESEARCH 2005)

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Our new master plan, "RESEARCH 2005", designed to cover the five years starting with fiscal year 2005, has five basic activity policies: (1) The creation of railway technologies for the 21st century, (2) The display of integrated power as a railway engineering group, (3) Quick response to needs, (4) The communication of railway technologies to the next generation and accumulation of basic technologies, and (5) The dissemination of railway technologies and communication of railway-related information. On the basic of these policies, we intend to carry out various activities, including research and development (R&D).

1. R&D

In order to concentrate our power and effectively implement R&D activities in line with the basic activity policies mentioned above, we have set "R&D objectives" (Reliability, Convenience, Low cost and Environmental compatibility), which define the directions of our R&D, and "prioritized R&D objectives" (R&D for the future of railways, Development of practical technologies and Basic research for railways), which clearly shows the R&D items to be focused on (see Fig. 1).

(1) R&D for the future of railways
We shall positively tackle themes that will enable us to achieve technological breakthroughs for the future of railways, and give our minds to putting the R&D results into practical application in 5 to 10 years. Table 1 lists the R&D themes to tackle for railways in the future. As an example, the "Development of high-speed, large-capacity information and telecommunication technologies for railways" shown in the table, features common specifications of the telecommunication infrastructure that will be established in order to offer an advanced network service to passengers on trains running at high speeds. In the "Development of fuel cell vehicles", which is positioned as one of the most important themes relating to the environment and energy issues, we shall conduct running tests with railway vehicles on which fuel cells are mounted. In line with the theme "Application of linear motor car technologies to the conventional railway system", we shall carry out R&D into applying advanced technologies that have been developed for MAGLEV, such as the superconductivity and linear motor, to the conventional railway system. Specifically, we shall tackle, for instance, the development of superconducting magnetic bearings and a rail brake system which employs linear induction motors.

(2) Development of practical technologies
In response to specific requirements from JR Companies, we shall promote R&D that will help them to solve problems in the field. In addition, we shall set our voluntary themes to focus on the technological fields where the development shall be given top priority. Furthermore, we shall continue with contract-based research and development.

(3) Basic research for railways
We shall carry out "analytical research" into the elucidation of railway-specific phenomena such as dynamics and tribology, and simulations of non-steady state aerodynamic phenomena. In addition, we shall try "exploratory and introductory research" aiming at applying new technologies, materials and research techniques to railways, such as the possibility of applying nano-materials to railways, etc.

2. International Activities

By attending various international conferences, including meetings of the World Congress on Railway Research (WCRR), we shall strive to promote the exchange of information on railway technology. In addition, we shall engage in joint research with research organizations in Europe and Asia, and help establish international standards for railways.

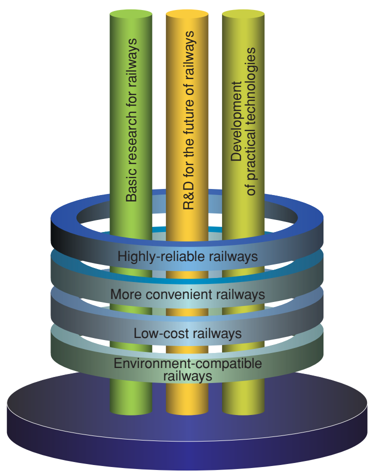

Figure 1. R&D activities of RTRI.

Table 1. Themes of R&D for the future of railways

R&D Objective	Theme
Highly-reliable railways	[Improvement of train running safety] • Configuration of signaling systems with RAMS index and its application • Development of method to evaluate characteristics of vehicle dynamics with a hybrid simulator [Securing of stable transportation] • Evaluation of earthquake-resistance of existing railway facilities and implementation of seismic measures • Application of sensing technology and information technology to railway facilities management
More convenient railways	[Improvement of convenience] • Development of high-speed, large-capacity information and telecommunication technologies for railways • Improvement of efficiency of transportation planning based on dynamic demand forecast [Improvement of comfort] • Development of human simulation technologies to improve safety and comfort
Low-cost railways	[Reduction of maintenance cost] • Creation of models to simulate rail damage and ballast track deterioration and evaluation of techniques to reduce maintenance costs • Development of a new maintenance-free and low-noise track
Environment-compatible railways	[Noise-less railways] • Development of a tool to predict rolling noise and structure-borne noise and measures for noise reduction [New energies] • Development of fuel cell vehicles • Application of linear motor car (MAGLEV) technologies to the conventional railway system

Development of Magnetic Rubber Damper with a Constraining Layer (MRDC)

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Recently, with the increase in demand for faster railway cars (from railway users) and for a quieter living environment (from communities along railway lines), there is a growing need to control railway noise and vibration. Of the various railway facilities, steel bridges are one of the major sources of noise and vibration. Accordingly, controlling their noise and vibration has become an important problem. The steel railway bridges are characteristic in that the noise (structure-borne noise) due to the vibration of girder members is extremely loud. Because of this, providing the girder members with a damper has been studied as a measure to reduce the noise and vibration of steel railway bridges. Most conventional dampers are of the type that is bonded to the girder. Since the work with dampers of this type requires a number of processes, including the surface preparation of the vibrating body (base layer), a high-performance damper which offers better workability is called for. Under these conditions, we have developed a magnetic rubber damper with a constraining layer, MRDC, as shown in Figs. 1 and 2.

This new damper consists of a constraining layer (galvanized steel sheet) laminated with a magnetic rubber layer. The magnetic rubber layer is made of butyl rubber with added ferrite powder (particle size: 5 to 10 μm) for magnetization. The constraining layer is used to improve the damper performance (e.g., the shear deformation can be amplified by constraining the magnetic rubber damper). As shown in Fig. 3, MRDC utilizes the magnetic attraction of the magnetic rubber layer to facilitate installing it to the steel vibrating body. The performance of conventional dampers depends upon the internal loss due to the shear deformation of the rubber layer. With MRDC, the internal loss of the magnetic rubber layer is smaller than that of the rubber layer of a conventional damper, but, the frictional loss due to the slide displacement between the magnetic rubber layer and the base layer (vibrating body) comes into action, in addition to internal loss of magnetic rubber layer. Therefore, as shown in Fig. 4, thanks to the effect of frictional loss, which is little influenced by temperature, MRDC retains its high performance over a wide temperature range, whereas the conventional damper shows high performance only within a certain limited temperature range, because of the temperature dependence of the rubber layer.

As shown in Fig. 3, the levels of noise at a steel bridge on a conventional JR line were measured before and after application to the web plate of the main girder of MRDC. As shown in Fig. 5, at a measuring point about 12.5 m from the center of the near-side track, a noise level decline of about 3 dB was observed over a wide frequency range. Thus, it was confirmed that MRDC was effective in reducing the noise produced by steel railway bridges.

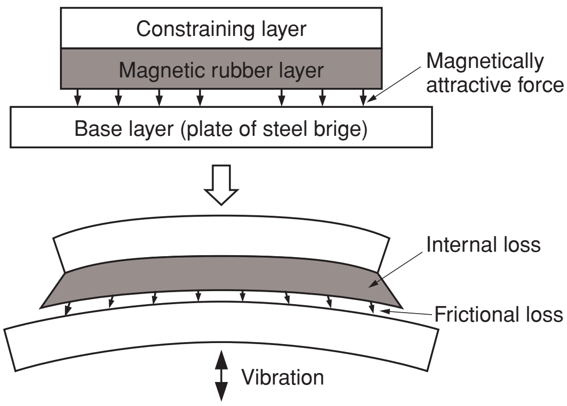

Figure 1. Structure and vibration damping mechanism of magnetic rubber damper with a constraining layer (MRDC).

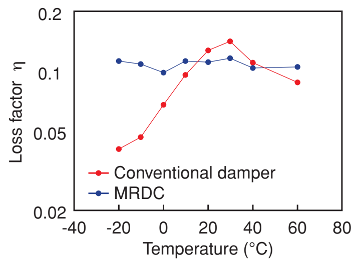

Figure 4. Loss factor of MRDC and conventional damper.

η is loss factor at 500Hz measured by the resonance method with two beam-type samples whose size was 225mm long × 25mm wide × 5.5mm thickness on both sides of a steel beam whose size was 500mm long × 25mm wide × 10mm thickness

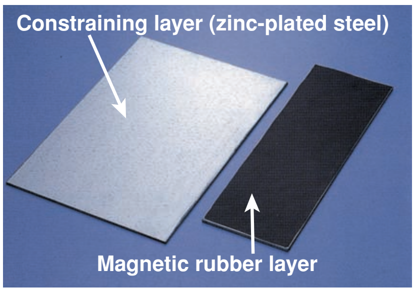

Figure 2. A picture of MRDC.

Figure 3. A picture of installation of MRDC.

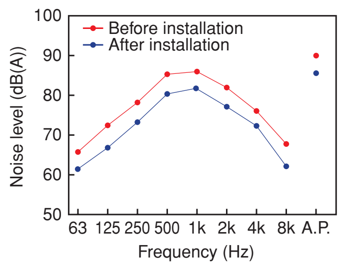

Figure 5. Measuring result of noise level around steel railway bridge before and after installation of MRDC (at a point distant from the center of near side track).

Adhesive Waterproof Sheeting for Preventing Water Leakage into Underground Structures

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Naoyuki YAGUCHI Masaru TATEYAMA

Introduction

In subway construction works, underground concrete structures in stations, or sections under a thin overburden layer, are built by the cut-and-cover tunneling method. With those underground structures, damage to various facilities inside the structures caused by the leakage of water, or the extra costs required to prevent water leakage, can become a problem. As a measure to prevent the leakage of water into an underground concrete structure, the pre-waterproofing method is used, in which waterproof sheeting or some other suitable covering is applied to the earth-retaining walls before construction of the structure (Fig. 1). However, even with this method, it is difficult to prevent the leakage of water completely. One of the conceivable causes of water leakage is local damage to the waterproof sheeting. Namely, with conventional waterproof sheeting, it is considered that if the sheeting is damaged, the groundwater that seeps through the damaged part flows freely between the sheeting and the structural concrete, and therefore the water leaks through cracks in the concrete regardless of where the sheeting is damaged (Fig. 2(A)). In view of this, we have developed a new type of waterproof sheeting which prevents the leakage of water more effectively. This new sheeting, called adhesive waterproof sheeting, forms tight chemical bonds to the structural concrete, and thereby prevents the water from flowing between the sheeting and the concrete, even if the sheeting is partially damaged (Fig. 2(B)).

Construction of adhesive waterproof sheeting

As shown in Fig. 3, the newly developed adhesive waterproof sheeting is composed of three layers—adhesive layer, protective layer and waterproof layer. The adhesive layer is made of a special ethylene-vinyl acetate copolymer with a high affinity for structural concrete. The protective layer, which prevents the sheeting from being damaged by rugged surfaces of the soil-mortar underground wall, is made of polyester cloth. The waterproof layer is made of an ethylene-vinyl acetate copolymer that has proven performance in the NATM method, etc.

Verification of performance of adhesive waterproof sheeting

To verify the performance of the adhesive waterproof sheeting, we carried out watertightness tests, strength tests, etc. As a result, it was confirmed that the sheeting had sufficient waterproofing performance and bond strength even under high water pressure of 500kPa. In order to confirm the adhesion between the sheeting and concrete, and the applicability of the sheeting, we also carried out a full-scale work execution test in the field. As a result, it was confirmed that the sheeting that was bonded tightly to the entire concrete surface showed no damage or deformation under fluid pressures during concrete placement, and fitted the irregular surface of the soil-cement wall satisfactorily, displaying good applicability (Fig. 4). In addition, the measured bond strength demonstrated that the sheeting would develop sufficient strength even in practical application. From all these results, it was confirmed that when the adhesive waterproof sheeting was used in actual works, the free flow of groundwater between the sheeting and concrete could be effectively prevented. Since its applicability in actual works has been sufficiently proved, the adhesive waterproof sheeting is being increasingly used in subway construction work, by the cut-and-cover tunneling method (Fig. 5).

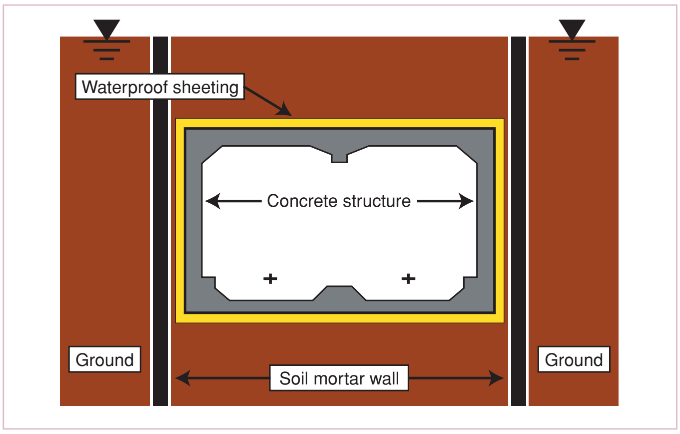

Figure 1. Conceptual diagram of cut-and-cover tunneling method

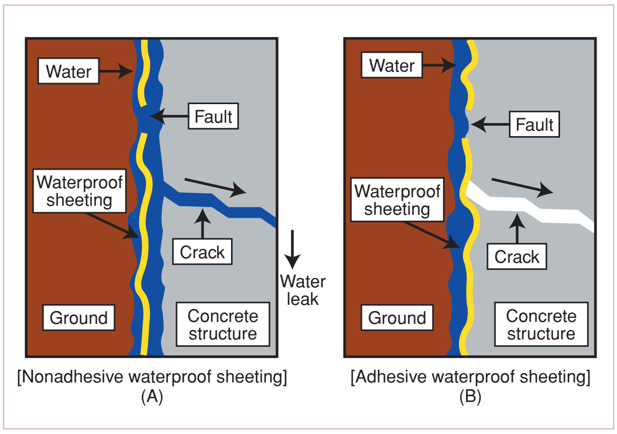

Figure 2. Mechanism of water leakage

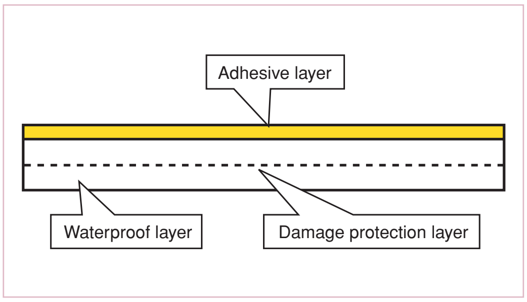

Figure 3. Structure of adhesive waterproof sheeting

Figure 4. Adhesive waterproof sheeting bonded to concrete

Figure 5. Adhesive waterproof sheeting being applied in tunnel

A Study of Method for Assessing The Overall Environmental Impact of Railways

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In modern society, there is a cry for measures to curb global warming and other far-reaching environmental impacts, as well as local environmental impacts (environmental pollution, etc.) that have long presented various different problems. Under this condition, industry has been striving to understand and to reduce emissions of environmental pollutants. Recently, efforts have also been made to assess the effects of those pollutants on the environment and economy.

In view of this, we have carried out a quantitative analysis of the global environmental impact of transportation facilities by means of life cycle assessment (LCA). The assessment method we use is the Japanese version of the life cycle impact assessment method, based on endpoint modeling (LIME) that has been advanced in the LCA project?an R&D project sponsored by the Ministry of Economy, Trade and Industry. This assessment method consists of calculating the amounts of various environmental pollutants emitted from all transportation facilities (inventory analysis) and the effects of the individual pollutants on the environment (impact analysis), converting those effects in terms of monetary value, and assessing them as external costs (Fig. 1).

In order to reach external costs, we first calculated the amounts of environmental pollutants (CO2, NOx, SOx) emitted from various types of transportation facilities. For the Tokaido Shinkansen, giving consideration to its life stages, we studied the quantities of materials and energies used in the development of ground facilities and the manufacturing, operation and maintenance of vehicles, and calculated the masses of the individual pollutants (Fig. 2). Concerning automobiles and aircraft, we calculated the masses of individual pollutants emitted from their infrastructure against the yen amounts of transactions shown in the latest inter-industry relations table. The quantities of energy used were obtained from the latest statistics.

On the basis of the calculated amounts of pollutant emissions, for each of various types of passenger transportation facilities, we calculated the external cost per person between Tokyo and Shin-Osaka (distance: 551 km). As a result, it was found that the external cost of the Shinkansen was about ¥31/person/551 km. On the other hand, the external cost for the national average of railways in Japan in the same 551 km section was estimated to be about ¥73/person (Fig. 3).

Converting environmental impacts in terms of external cost by means of LIME as above has the advantage of permitting any industry to easily express various kinds of environmental impacts numerically. In the future, we intend to improve the accuracy of the assessment method and apply it in various other sections.

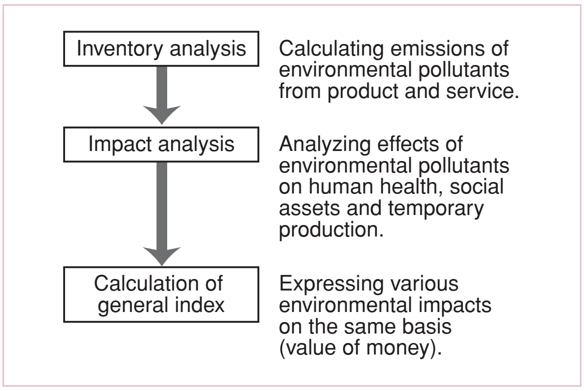

Figure 1. Overall environmental assessment based on LIME.

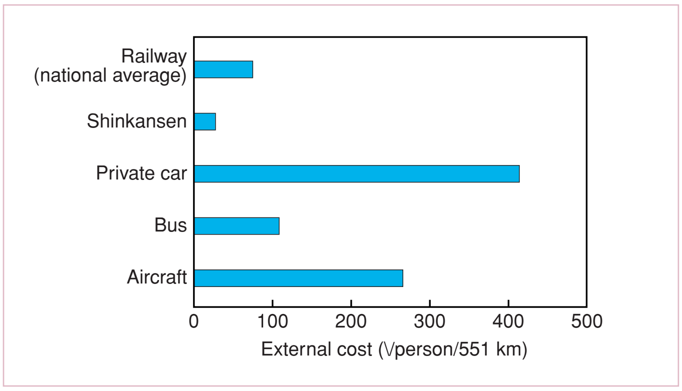

Figure 3. External cost by transportation facility between Tokyo and Shin-Osaka.

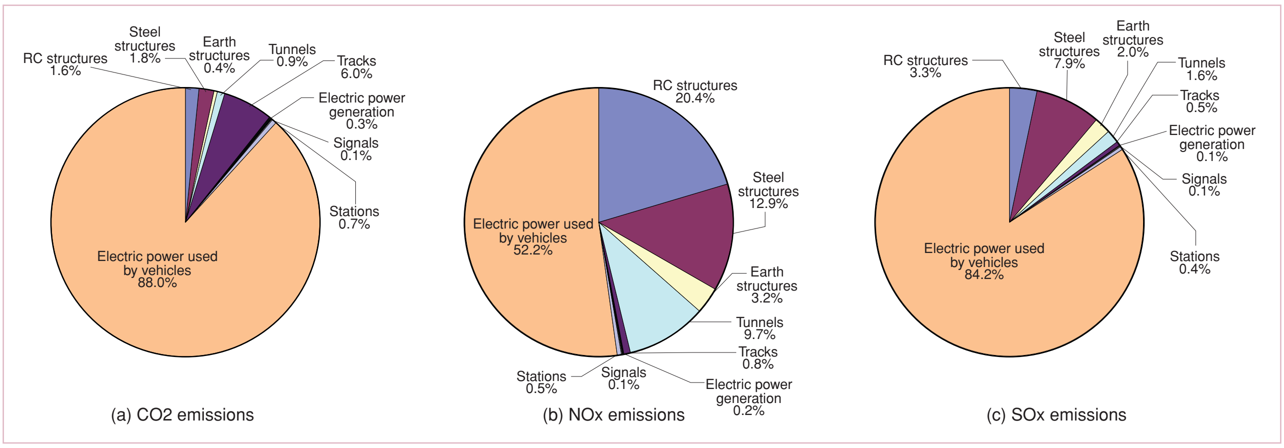

Figure 2. Breakdown of emissions of environmental pollutants by type in the construction, manufacturing and operation of Tokaido Shinkansen.

Manufacturing and Applications of High Temperature Superconducting Bulk

Hiroyuki FUJIMOTO
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Superconducting technology is considered to be a promising technology for saving energy, while allowing for large currents and high magnetic fields, creating new functions and potentially helping to solve energy problems in the future. So far, advanced R&D has been carried out on superconducting materials and their application in developing new electrical equipment.

A high temperature superconducting substance (*1) whose critical temperature is higher than 30 K was discovered in the latter half of 1986. In several years that followed, superconducting substances (*2) with a critical temperature of 90 K to 100 K or higher were discovered one after another. There is a high level of expectation regarding the future application of these substances as new materials which would permit bringing about a superconducting state by using easy-to-handle liquid nitrogen (77 K) in place of liquid helium (4.2 K).

There are two different forms of superconducting materials. There is "wire", which has been used mainly in low-temperature, metal-based superconducting materials (*3) and "bulk", which was found to have excellent superconducting characteristics in the process of research and development on high-temperature superconducting materials.

In order to develop larger-sized superconducting bulks having better superconducting properties we have studied material manufacturing techniques, evaluated basic material properties and discussed the possibility of applying those bulks to practical applications (Table 1).

The candidate materials we used were silver (Ag)-added, Y-based superconductors (*4) and Ag-added, rare earth (RE) -based (*5) superconductors (*6).

Manufactured using a melt process, these superconductors have excellent superconducting properties at 77 K and are considered capable of generating high magnetic fields of tesla (T) order.

In the manufacturing of a superconducting bulk, the microstructure of the material varies markedly according to the raw material composition and heat treatment conditions. The reason why Ag is added to the composition is that this element is expected to improve both the microstructure and the mechanical and electromagnetic characteristics of the material, and that it permits the use of a lower heat treatment temperature.

Concerning the heat treatment conditions, we discussed the melting and solidification method in which, after the maximum temperature is reached, the temperature at which crystals grow and the degree of undercooling for heat treatment are kept constant (Fig. 1). Compared with the temperature gradient method in which the solidification temperature is lowered with the lapse of time, the method we adopted is considered to facilitate temperature control and promote the growth of crystals.

In the seeding process, which has to do with the starting point of crystal growth, we used an Nd-based thin-film seed in place of a single crystal or bulk crystal, which has been commonly used in the past. This thin film has a number of advantages—good crystallinity, stable composition, easy machining, less contamination of the material surface, etc. Since the effectiveness of the thin-film seed and the stable growth of crystals were confirmed, we made a Y-based bulk 40 mm in diameter and about 15 mm in thickness (Fig. 2 and Table 2).

*1: lanthanum (La)-based
*2: yttrium (Y)-or bismuth (Bi)-based
*3: NbTi (niobium titanium) etc.
*4: $YBa_2Cu_3O_X$
*5: samarium (Sm) etc.
*6: $RE_{1+X}Ba_{2-X}Cu_3O_X$

Table 1. Possible superconducting bulk applications in railways.

Applications	Basic functions
Superconducting permanent magnet	Magnetic field by trapping flux
Flywheels	Storing electricity by magnetic levitation (bearing)
Motors	Generating by trapping flux
Fault current limiter	Controlling transmission by current flow & normal resistivity
Actuators	Transferring from electricity to power by trapping flux
Magnetic Separation	Segregating by trapping flux
Magnetic shielding	Expelling magnetic field by diamagnetism or flux penetration
Current leads	Transmitting by current flow for equipment

Table 2. Effects of high-temperature superconducting bulk manufacturing conditions applied in the present study

Manufacturing conditions	Effects
Y-based/rare earth element -based super conducting bulk (melt process)	Superior superconducting properties
Initial raw material composition with excess Y211 phase	Higher critical current density
Ag addition	Improved mechanical strength
Nd base/MgO substrate; thin-film seed (seeding at room temperature)	Improved homogeneity, stability and safety
Isothermal heat treatment (holding temperature at a constant undercooling rate)	Easier temperature control; possibility of mass production
Heat treatment in open air	Simple

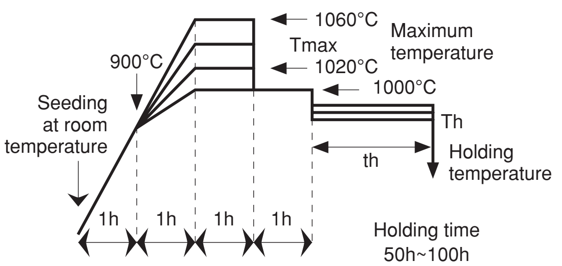

Figure 1. Heat treatment pattern discussed in the manufacturing of high-temperature Y-based superconducting bulk.

Figure 2. Photograph of the surface of our Ag-added Y-based high-temperature superconducting bulk (maximum heat treatment temperature: 1,060 °C, undercooling temperature: 10 °C).