Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

Octorber 31, 2006 No. 15

Railway Technical Research Institute
2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN

URL: http://www.rtri.or.jp

GENERAL INFORMATION

ARTICLES

Foreword

Kazuhiko TEZUKA
Director, Planning Division

The Railway Technical Research Institute (RTRI) will celebrate its 20th anniversary in December 2006. RTRI was established as an incorporated foundation on December 10, 1986, as part of the breakup and privatization of Japanese National Railways (JNR). It began its research and development in earnest on April 1, 1987, when the JR group of companies was launched.

Every five years, RTRI draws up a new master plan and implements it to fulfill management policies and the original RTRI vision. The current master plan, for the fiscal years 2005 to 2009, is called Research 2005, and promotes the following five basic courses of action:

- Create new railway technologies for the 21st century
- Demonstrate the comprehensive potential of a railway engineering group
- Respond rapidly to the needs of society and the JR Group of companies
- Transfer railway technologies and acquire basic technologies
- Spread knowledge of railway technologies and transmit railway-related information

During the last 20 years, we have depended considerably on the intellectual and physical assets accumulated by JNR over its many years of managing Japan's national railway services. Although some of our equipment and infrastructure was installed since our establishment, much of our testing facilities, and the land and buildings we use for research, were inherited from the former JNR, as were many of our staff members who developed their technical expertise during their years with JNR.

During the last two decades, some companies within the JR Group have established their own technical research centers to actively pursue development programs with manufacturers, universities, and public research institutes that were transformed into independent corporate entities.

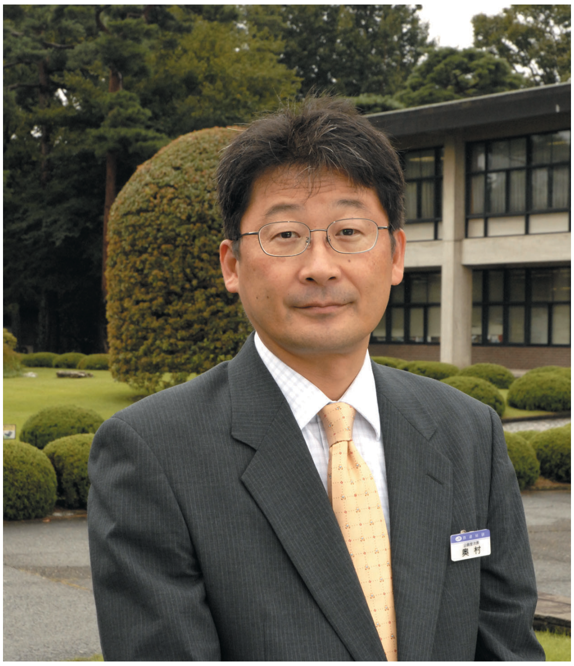
Because of these various circumstances, RTRI must give its research activities a new perspective for the next 20 years, while at the same time fully using assets acquired from JNR. One example of these assets, and the most important, is our human resources. Sixty percent of RTRI's technical staff joined us since we became an independent incorporated foundation two decades ago. Some fundamental challenges now facing our Institute are to ensure that this technical experience is passed on to younger generations, to train more high-caliber technical staff, and to secure even more highly qualified human resources. Another important goal is to replace testing facilities and equipment that are becoming obsolete, and to introduce new, more advanced ones.

The vision that inspired the establishment of RTRI reinforces our intention to continue working well into the future for the betterment of society, taking advantage of the most advanced railway technology that we can possess.

手塚和彦

RTRI Research and Development Projects Promoting Advances in Rail Transport

Fuminao OKUMURA, Ph.D.
Deputy Director, Planning Division



When conducting research and development for future advances in rail transport, Railway Technical Research Institute (RTRI) promotes small-scale projects that target technical breakthroughs, aiming for the practical application of R&D results within approximately five to ten years. RTRI s master plan for the fiscal years 2005 - 2009, called Research 2005, envisages 12 R&D projects.
These projects were given the following themes:

- They should respond to the needs of companies in the JR Group, and to social trends
- They should aim for the development of advanced technologies and for improvements in rail transport
- They should take advantage of the strengths and R&D expertise that RTRI has in specific areas
- They should lead to the development of practical technologies, and the resolution of critical problems surrounding that development

Outlines of four major R&D projects and the titles of the other eight projects launched by RTRI in fiscal 2005 are listed below. All projects aim to promote future advances in rail transport.

(1) Configuration and application of a signaling system evaluated with the RAMS index
This project will study and propose methods for evaluating the RAMS (Reliability, Availability, Maintainability and Safety) characteristics of a signaling system, and methods to improve such evaluation indices, in order to effectively establish, at low cost, a signaling system having excellent RAMS characteristics.

(2) Development of a method to evaluate the characteristics of vehicle dynamics, using a hybrid simulator
This project will develop a system that effectively evaluates vehicle characteristics using mainly Hardware-In-the-Loop (HILS) Simulation (HILS) techniques, symbiotically linking computer simulations, component testing equipment, and vehicle testing stands. HILS are hybrid in nature, using testing equipment that coordinates the use of computerized dynamic models with the simultaneous use of actual equipment, while transmitting their responses to a computer system.

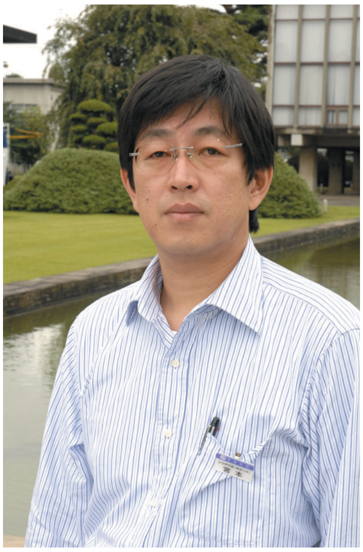
(3) Improvement in the evaluation of existing railway facilities ability to withstand earthquakes, and development of better measures for making facilities more earthquake-resistant
Railway systems are composed of a wide variety of component parts, mainly structures, track, an electric power system, signaling equipment and rolling stock. Antiseismic measures have traditionally been applied to each of these individual component parts. In reality, though, each of these parts influences the others. RTRI's antiseismic research emphasizes this fact while developing (i) methodologies to evaluate, using common criteria, the behavior of railway facilities during seismic activity, and (ii) methodologies to determine what type of earthquake-resistance measures should be implemented, taking into consideration quantitative factors such as investment cost effectiveness.

(4) Development of human simulation technologies to improve safety and riding comfort
Simulation techniques have advanced rapidly and are now used to examine human factors such as passenger traffic patterns, behavior, and decision-making patterns. RTRI is building on these advances while developing new simulation techniques that can be used to better evaluate and predict the safety and comfort levels of passengers and railway personnel.
Titles of the other eight projects are as follows:

(5) Application of IT and sensing technologies to equipment management
(6) Development of a tool to predict rolling noise and structure-borne noise, and development of noise reduction measures
(7) Development of high-speed mass storage information and telecommunication technologies for railways
(8) More efficient transport planning based on dynamic demand estimation
(9) Creation of rail damage/ballast track deterioration models, and evaluation of maintenance work saving technologies
(10) Development of a new low-maintenance, low-noise track
(11) Development of fuel cell vehicles
(12) Application of linear motor technologies to the conventional railway system

A Study of the Dynamic Behavior of Railway Vehicles During Seismic Activity

Takefumi MIYAMOTO
Senior Researcher, Vehicle Machanics, Railway Dynamics Division



A railway vehicle derails as a result of seismic activity either because of deformation of a railway structure or the track, or because of track vibration caused by the earthquake itself. Since the Hyogo Prefecture Nambu Earthquake of 1995, railway structures in Japan are being made more earthquake resistant through the gradual improvement of design standards that adopted the latest techniques.

With regard to the derailment of railway vehicles as a result of seismic vibrations themselves, the Railway Technical Research Institute (RTRI) has performed numerical simulations, and conducted advanced experimental research using a vibration test rig to examine the behavior of an actual Shinkansen bogie. The results have been reflected in new design standards for railway structures, and are being used to improve the seismic safety of railway systems.

(1) Running safety limits in the presence of sinusoidal waves

We developed our own simulation program to analyze the behavior of railway vehicles during an earthquake. The program uses a conventional vehicle running simulation model with added features to permit the accurate analysis of such factors as oscillatory input under the rails, wheel jump on rails, and the large roll displacement of vehicles.

Using this simulation model, we determined a running safety limits during the presence of sinusoidal waves (see Fig. 1). Figure 1 indicates sinusoidal wave vibration frequency (lateral axis) and maximum amplitude (longitudinal axis) limits required to avoid a derailment when vibrations are input from directly under a running vehicle. From this it can be determined that if the relative wheel/rail lateral displacement is more than 70 mm, a derailment is almost sure to occur.

(2) Experiments using a Shinkansen bogie on a vibration test rig

To determine the validity of our simulation analyses, we performed experiments using a vibration test rig.

The test objects used in the experiment are shown in Fig. 2. We installed a straight 5-m length of track on the large vibration rig, placed an actual Shinkansen bogie on the track, then mounted a load equivalent to half the weight of a Shinkansen car on the bogie.

The total weight of these test objects was 35 tons. Vibrations were input in mainly a lateral direction. During the experiment, vibration frequency amplitude was gradually increased until the wheels jumped 3 mm or more above the rails.

Fig. 3 compares results obtained from this experiment with the simulation results. The figure's lateral axis indicates vibration frequencies, while the longitudinal axis indicates input amplitudes when a wheel jumped 3 mm or more. These results validated results obtained through simulations.

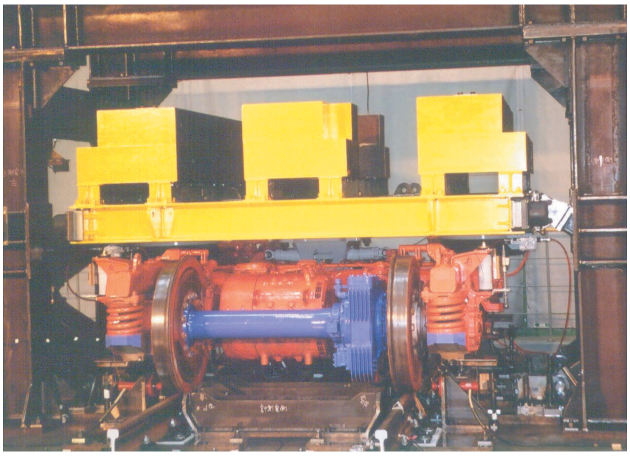


Fig. 2 Photograph of testing plant

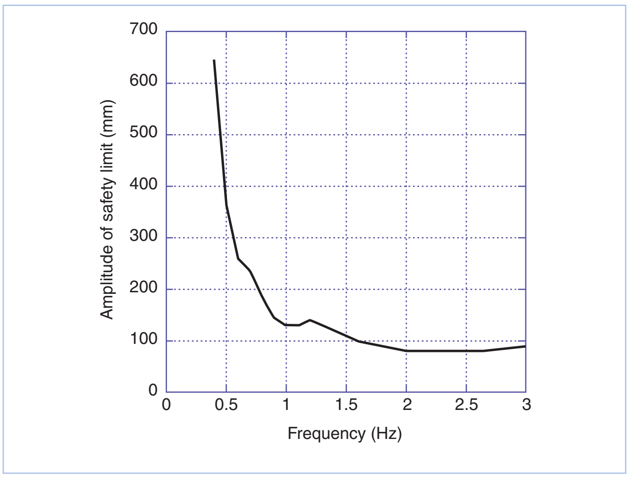


Fig. 1 Running safety limits by relative displacement between wheel and rail 70mm
- Five lateral sinusoidal waves, simulated run of Shinkansen vehicle at 350 km/h on straight track.

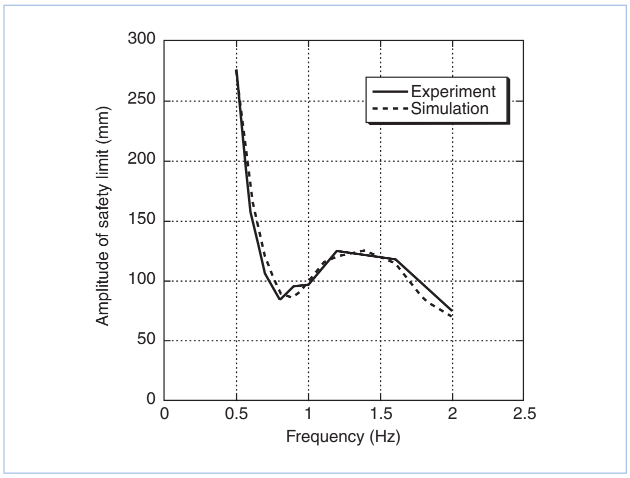


Fig. 3 Comparison between experiment and simulation results for safety limits when a wheel jumped 3 mm or more
- Five lateral sinusoidal waves, load equivalent to half the weight of a Shinkansen carbody, stopped on straight track.

Observation, Experimentation and Analysis of Pressure Waves Generated When a Train Passes a Nearby Structure

Hajime TAKAMI
Assistant Senior Researcher, Aerodynamics, Environmental Engineering Division

Low-frequency sounds are slight pressure fluctuations with frequencies in the range of approximately 1 to 100 Hz. They are hardly perceptible to the human ear, yet have given rise to concern in Japan over the last decade because they can cause the rattling of house windows and shutters, and can also cause physiological and psychological discomfort, such as ringing in the ears and an unpleasant sensation of pressure.

Micro-pressure waves generated at tunnel portals when a high-speed train enters a tunnel have long been observed along railway lines as low-frequency sounds. But even along some open sections of line, pressure waves may be radiated from a nearby structure when a high-speed train passes. These pressure waves, in the form of weak low-frequency sounds, do not cause a problem at present, but they could negatively affect the adjacent environment when trains operate at even faster speeds in the future.

Our research team therefore conducted on-site measurements along open track sections to examine phenomena when a high-speed train travels under an overpass (Fig. 1). We measured pressure waves that differed according to train speed, overpass size, and the location of the observation point.

We then performed experiments using a model scale apparatus and conducted acoustic analyses, to determine the speed dependencies, distance attenuation and directional characteristics of pressure waves. We were able to show that mechanisms generating pressure waves involve both micro-pressure waves and a combination of waves generated when the train enters and leaves the portals (with the overpass acting as a short tunnel). We used this knowledge to analytically predict the characteristics of pressure waves radiated from an overpass that is long enough to possibly cause a problem during high-speed operations. Predicted values agreed well with the results of our experiments (see Figs. 2 and 3).

This research has further improved the methodology for analyzing pressure waves, thereby aiding in the prior determination of trackside low-frequency sound and pressure wave conditions that would exist under higher speed operations for Shinkansen and other high-speed trains.

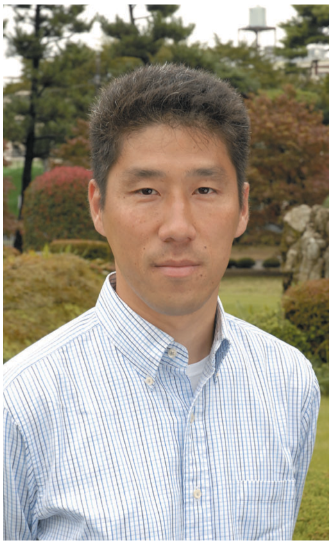


Fig. 1. Overpass

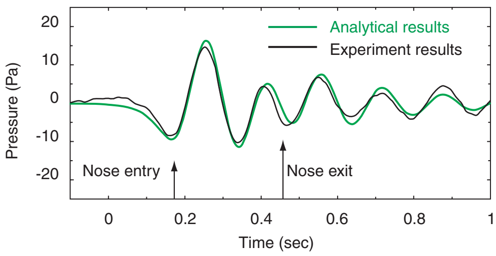


Fig. 2. Pressure waves observed during experiments and determined through analysis
[Train velocity 350 km/h; overpass width 24 m]

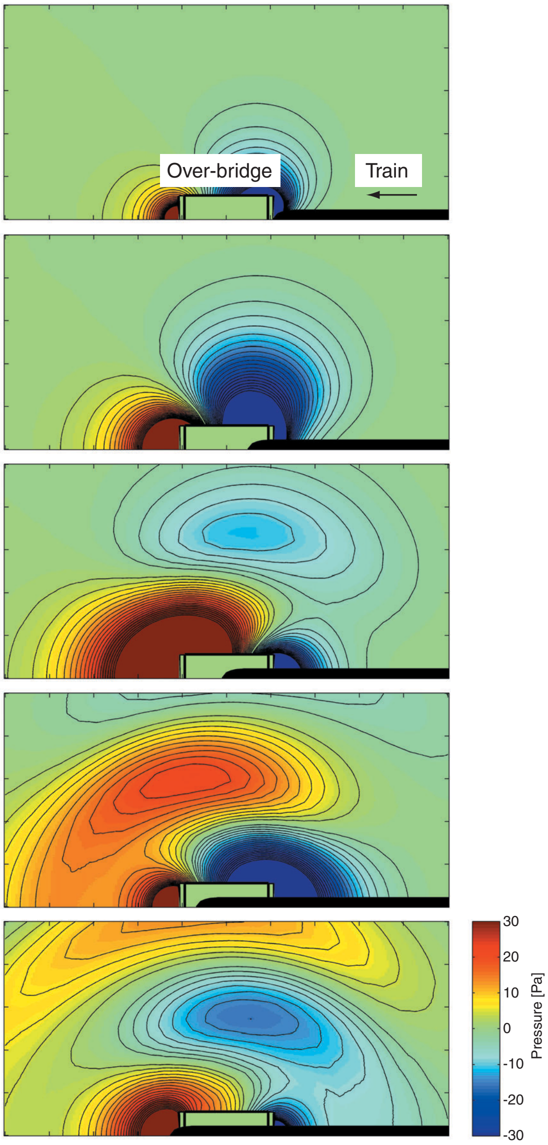


Fig. 3. Spatial distribution of instantaneous acoustic pressure, obtained by analysis
[Train velocity 350 km/h; overpass width 24 m]

A New Method to Evaluate Ride Comfort Under Braking Conditions

Koji Omino
Senior Researcher Ergonomics, Human Science Division

Faster deceleration when stopping a train at a station would improve transport efficiency. This is an important technical goal, due to the need for prompt mass transit services and short train intervals. We performed tests with human subjects to examine braking patterns that would not reduce ride comfort even under higher deceleration rates, and to clarify the relationship between deceleration, derivative of deceleration (jerk), and ride comfort. We have also proposed a ride comfort evaluation method based on the test results.

Ride Comfort Levels during Braking

We assumed the braking patterns used at stations to stop a train, and performed tests on the Maglev test line of the Railway Technical Research Institute, with human subjects standing on board the train (Fig. 1). Our tests revealed the previously unknown relationship between deceleration, jerk and ride comfort in a high deceleration range. Fig. 2 shows ratios of passengers who could not adequately adjust to the various braking pattern used to stop the train, and these serve as one scale for measuring ride discomfort levels. The figure clearly indicates the rate at which ride comfort deteriorates as deceleration increases. A negative impact on ride comfort was observed even at approximately 0.1m/s^3 jerk difference, and there is a tendency for ride comfort deterioration rates to shift toward higher values as jerk increases.

Proposals for a Ride Comfort Evaluation Index and Optimum Braking Patterns

We used the test data to propose an index to evaluate ride comfort levels during deceleration and jerk that take the form of a trapezoidal braking pattern (Fig. 3). The curves in Fig. 2 are based on this index, and show that ride comfort deteriorates as the index value increases. We also analytically obtained the deceleration and jerk values that minimize the indices for various combinations of initial speeds at braking and stopping distances, and have proposed train-stopping braking patterns that offer optimum ride comfort.

Future RTRI Research in this Field

In the future we plan to study the practical application of brake controls, in order to introduce our proposed braking patterns to commercial operations. During those studies we will also examine ways to widen application of the index so that various other factors influencing ride comfort during braking, including the congestion often seen on commuter trains, can be taken into account. In addition, in order to examine ride comfort more effectively, we intend to develop a system that simulates the swaying of standing passengers when brakes are applied, using the ride comfort data obtained during the above-mentioned study.

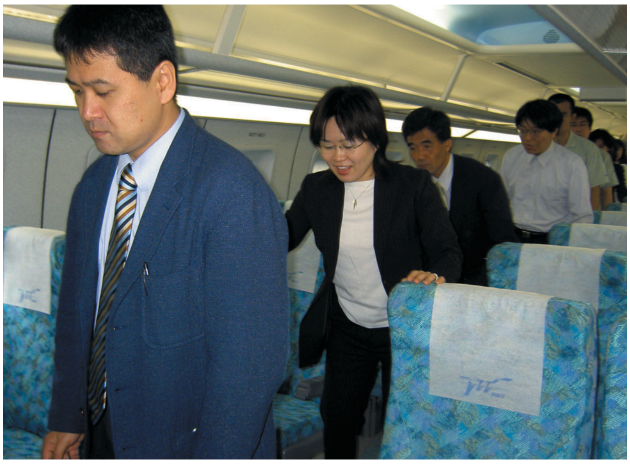


Fig. 1 Ride Comfort evaluation test during braking

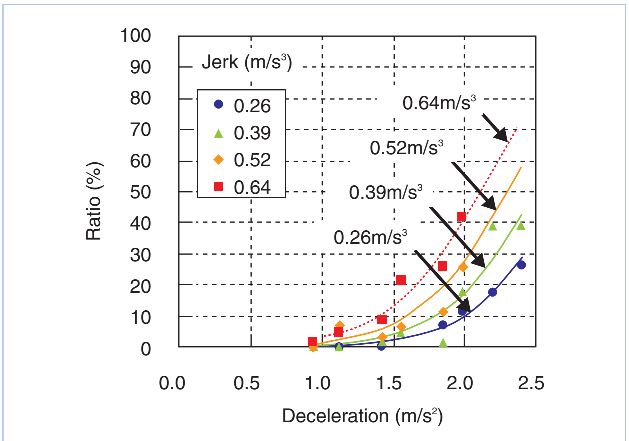


Fig. 2 Ratio of passengers unable to adequately adjust to braking patterns

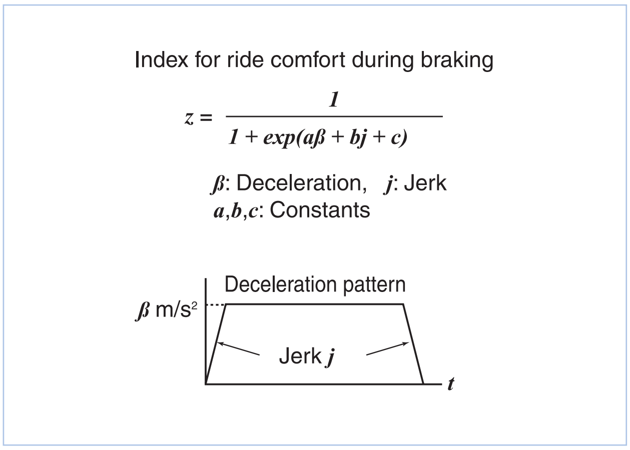


Fig. 3 Index for ride comfort during braking
The greater the value, the poorer the ride comfort

Ground Coil Electromagnetic Vibration Tests Using the Magnetic Field of a Superconducting Magnet

Minoru Tanaka
Assistant Senior Researcher, Electromagnetic Applications, Maglev Systems Technology Division

Ground coils installed along the guideway of a superconducting magnetically levitated transportation system are vibrated by electromagnetic forces when a vehicle passes. To ensure the reliability of the entire system, it is important to verify the dynamic durability of ground coils. We therefore developed an electromagnetic vibration test apparatus for bench tests that can apply an electromagnetic force on a coil conductor as a distributed load, simulating the load conditions of an actual train operation, and that can evaluate the vibration characteristics and dynamic durability of the coil molding material under arbitrary running conditions.

Figs. 1 and 2 show the configuration and appearance of the test system, respectively. By installing the target ground coils so that they face the superconducting magnet (maximum magnetomotive force: 800 kA), and by applying the current from the inverter power supply under arbitrary conditions (maximum current: 2000 A), it was possible to simulate actual vibration conditions that occur when a train passes the coil. In addition, because a superconducting magnet generates a larger electromagnetic force than during actual operations, when it is placed in an alternating magnetic field, the ground coil was covered with a shield plate to insulate it from the alternating magnetic field and thus restrict magnetic vibrations. A ground coil cooling system and a soundproof chamber were also installed, and an automatic measuring and monitoring system that we had developed ourselves was used to enable unmanned long-time durability testing.

To confirm the equivalence between bench tests and actual operations, the coil was installed in the test system via load converters so that the load acting on the coil could be measured from 3 directions. Measurements confirmed that the electromagnetic forces acted on the coil as designed. In addition, with accelerometers mounted on the coil surface, we performed sweep tests of vibration frequency to confirm that the system can vibrate the coil at vibration acceleration rates equivalent to those experienced during actual operations.

Dynamic durability tests were performed using an actual coil for propulsion. 1.38×10^7-cycle vibration tests were performed under an electromagnetic force that generated approx. 1.2 times the ordinary stress on the coil's molding material. The vibration tests were performed only in the daytime, in consideration of temperature rise characteristics of coils on a commercial line. The test period was approximately 10 days. This test period corresponds to approximately 35 years of vibration on a commercial line, a fact determined by acceleration tests based on S-N curve characteristics obtained from separately performed fatigue tests of the molding material.

During the tests, accelerometers were mounted on various portions of the coil to observe how vibration acceleration rates change with time. As is shown in Fig. 3, acceleration increases slightly at measuring point ⑤ just after vibration is started, but this increase is small in value and saturates. This confirmed that there is no problem concerning coil dynamic durability. During visual examinations and insulating characteristic tests performed before and after the vibration tests, no change of properties was seen and a dynamic durability equivalent to 35 years of operation on a commercial line was confirmed. Results show that our ground coil electromagnetic vibration test apparatus can be used as an effective means to evaluate dynamic durability.

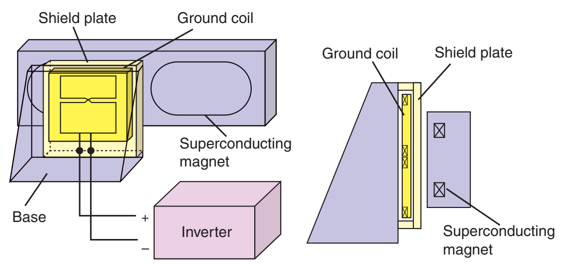


Fig. 1 Configuration of ground coil electromagnetic vibration test apparatus

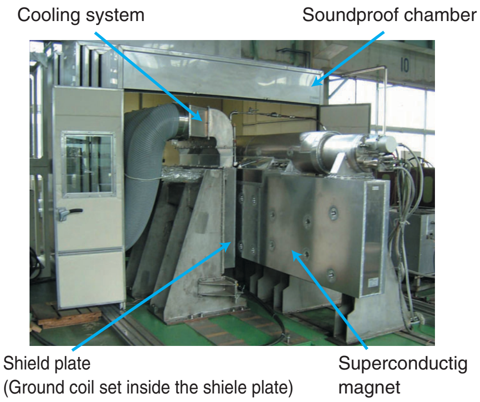


Fig. 2 Appearance of electromagnetic vibration test apparatus

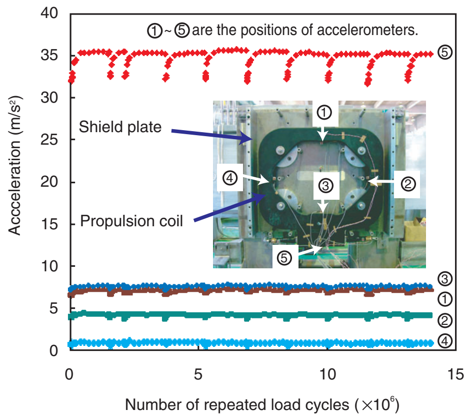


Fig. 3 Dynamic durability test results for a propulsion coil