Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

January 20, 2007 No. 16

GENERAL INFORMATION

ARTICLES

Railway Technical Research Institute
2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN
URL: http://www.rtri.or.jp

Railway Technical Research Institute Celebrates 20th Anniversary

Katsuji AKITA
President

The Railway Technical Research Institute (RTRI) was established in December 1986 as a non-profit institution to assume the functions of the R&D branch of the Japanese National Railways. (JNR was privatized and divided into seven railway companies soon after, in 1987.) Today, we have more than 500 technical researchers active in a wide range of fields from civil, electrical, mechanical and biological engineering to physics, chemistry and human science. Our basic research aims, for example, to further improve rail safety and preserve global environment, our research and development contribute to technical innovations in the Shinkansen and conventional rail systems, and our pioneering efforts focus on the development of a superconducting magnetically-levitated (maglev) transport system.

Over the last two decades we have achieved impressive results, contributing to greater rail transport safety, faster speeds for Shinkansen and conventional trains, lower costs for the construction, operation and maintenance of rail systems, and better rail services through the use of IT. Our basic railway research has examined issues such as wheel-rail interaction, ride comfort evaluation methods, aerodynamic factors and noise-generating mechanisms associated with higher speeds, the dynamic behavior of running rolling stock during earthquakes and strong winds, mechanisms leading to human errors, and railway system risk analysis.

Our R&D tools include a large-scale low-noise wind tunnel, which is among the world's most advanced, a rolling stock test plant to evaluate the motion characteristics of individual railcars, a simulator to evaluate ride comfort, and a supercomputer.

In collaboration with Central Japan Railway Company and the Japan Railway Construction, Transport and Technology Agency, we have constructed a test line for a superconducting maglev system. We have used the line to conduct test runs and promote the development of maglev technologies. In early 2005, the project achieved the establishment of the basic technology needed to place the system in commercial service. We are continuing our R&D efforts to further improve maglev system performance.

RTRI's R&D efforts are conducted in partnership with JR companies and in association with other railway-related companies and government-funded research institutes.

Several dozen of our researchers work also as visiting professors at Japanese universities, and we have established tie-ups with overseas entities such as the International Union of Railways (UIC), the Innovation and Research Department of the French National Railways (SNCF), railway research institutes in China and Korea, and universities and research centers in the United States and Europe. RTRI is an organizing member of the World Congress on Railway Research (WCRR). We provide technical consulting for projects targeting the introduction of Japanese railway technology in other countries, upon the request of governments, rail transport institutions and corporations.

Railways offer a number of advantages, particularly safety, high speed, on-time service, and environmentally-friendly operations, and it is important to further increase this competitive advantage to ensure the future expansion of rail transport. It is also important to form tie-ups with other modes of transport, to give users the convenience they want from rail services. Our R&D efforts will continue to support technical innovations to achieve these aims.

Our Railway Technical Research Institute, now 20 years old, will keep increasing its technical potential in order to create new rail systems for the 21st century.

秋田雄志

Railway Technical Research Institute: The Past Twenty Years, and the Future

The Railway Technical Research Institute (RTRI) was established on December 10, 1986 as an incorporated foundation, under authorization of the Ministry of Transport (now known as the Ministry of Land, Infrastructure, and Transport). Its establishment occurred prior to the division and privatization of Japanese National Railways to take over JNR's research and development facilities and staff. Since April 1987, RTRI has served as a research institute for the JR-group companies, and has achieved impressive development results.With the participation of many guests, RTRI celebrated its 20th anniversary on December 13, 2006 (see Fig. 1).RTRI intends to continue its research and development to achieve even more impressive results, thereby contributing to the further development of the world's rail technology. The following chronology lists RTRI's major accomplishments and events over the past 20 years.

Fig. 1 20th anniversary ceremony of RTRI

Fig. 2 Chairman Matsumoto (right) and President Akita (left) planting a commemorative tree

1986	**Dec.**	**10**	Establishment of the RTRI authorized by the Minister of Transport.
1987	**Apr.**	**1**	The RTRI inherited the R&D arm of Japanese National Railways upon its division and privatization.
1988	**Nov.**	**9**	First RTRI Lecture on "Improving the Railway System".
1990	**June**	**25**	Basic plans of the technological development of the superconducting magnetically-levitated transport system and the construction of the Yamanashi Maglev Test Line approved by the Minister of Transport.
	Nov.	**15**	New rolling stock test plant completed.
1991	**Mar.**	**31**	Test Plant E (human science) completed.
	Oct.	**16**	First railway technology exhibition (forerunner of the current RTRI Forum).
1992	**Sep.**	**29**	First lecture series on education (forerunner of the current Railway Technology Courses).
	Oct.	**13**	International railway research seminar on "R&D in World Railway -Today and Tomorrow-" (later developed into WCRR).
	Dec.	**15**	Japan-China joint research started.
1993	**Jan.**	**31**	Brake Test Stands completed.
1994	**Nov.**	**4**	RTRI website went on-line as the world's first official site on railway technologies.
	Nov.	**13**	Agreement on cooperative research concluded with the International Union of Railways (UIC).
1995	**Jan.**	**17**	Hyogo-ken Nambu earthquake (participation in recovery support activities).
	July	**27**	Agreement on the use of the Pueblo test line concluded with the Association of American Railroads (AAR).
	Nov.	**13**	Agreement on cooperative research concluded with French National Railways (SNCF).
1996	**June**	**5**	Large-scale low-noise wind tunnel completed.
	July	**1**	Yamanashi Maglev Test Center opened.
	July	**1**	Railway Technology Promotion Center opened.
1997	**Apr.**	**3**	Vehicle running tests started on the Yamanashi Maglev Test Line.
	June	**1**	The RTRI joined UIC.
1999	**Oct.**	**19-23**	World Congress on Railway Research 1999 (WCRR '99) held at the RTRI.
2000	**June**	**28**	Japan-Korea joint research started (forerunner of the current Japan-China-Korea joint research).
2003	**Mar.**	**31**	Rail Advisor Program established at the Railway Technology Promotion Center.
	Dec.	**2**	The world speed record of 581 km/h for a manned train (MLX01) attained on the Yamanashi Maglev Test Line.
2004	**Mar.**	**24**	First Symposium of CyberRail Study Group.
	Oct.	**14**	Railway Technology Promotion Center won the Japan Railway Awards' Special Award for 2004.
	Oct.	**23**	Niigata Chuestu earthquake (participation in recovery support activities).
	Oct	**27**	A running distance of 400,000 kilometers achieved on the Yamanashi Maglev Test Line.
	Nov.	**16**	Two-train crossing test at a relative speed of 1026 km/h on the Yamanashi Maglev Test Line.
2005	**Mar.**	**11**	The Committee for the Evaluation of the Technological Feasibility of Maglev commented that the key technology for practical application has been established.
	Apr.	**1**	New Master Plan (Research 2005) formulated.
2006	**Apr.**	**26**	Running Test of the World's first railway vehicle powered by a fuel cell.

Easy-to-use Ride Comfort Measuring Device

Akihiro HAGA
Assistant Senior Researcher, Vehicle Dynamics, Vehicle Structure Technology Division

1. Introduction

We developed a low-cost compact system that easily measures vibrations experienced by passengers on a running train, and also developed easy-to-use software that can evaluate ride comfort using acceleration data obtained through measurements performed using the system.

2. System configuration

2.1 Overall system

Fig. 1 shows the component parts of the easy-to-use ride comfort measuring system: a digital device to measure sway, a running motion data generator, and a laptop computer.

2.2 Acceleration sensor

Fig. 2 shows the digital device we developed to measure sway. The device is compact, inexpensive, uses little electricity and combines a number of functions: a 3-axis acceleration sensor (using silicon semiconductors and the piezoresistance effect), a digital signal processor, a power source connector, and a USB interface. Vibration data is transmitted through the USB cable and recorded on the laptop computer's hard disk.

2.3 Running motion data generator

Fig. 3 shows the running motion data generator. Speed data and vehicle location data are required as incidental data when conducting performance tests of rolling stock and motor vehicles. The running motion data generator generates speed and vehicle location data after receiving signals input by the marker, speed generator and GPS. The speed and vehicle location data are recorded in multiplex on one channel by double scaling, to eliminate the need for multiple recording channels.

3. Ride comfort evaluation

Use of the recorded acceleration data permits an evaluation of ride comfort, a frequency analysis, and a display of sway wave patterns. Results are output onto a spreadsheet, and the layout can be modified at will when compiling reports.

4. Track improvement

Obtained vibration data is filtered for each spectrum and plotted on a time axis, and a list is made ranking locations,

speeds and ride comfort coefficients that exceed target values. The compiled list is then transmitted to create a spreadsheet. Time sampled vibration data can be plotted on a distance axis, and data can be easily transferred to a track improvement database system such as MicroLABOCS. Integrated data management is possible.

5. Future development

We also intend to develop a system that will permit unmanned measurements at many locations.

Fig. 2 Digital device to measure sway

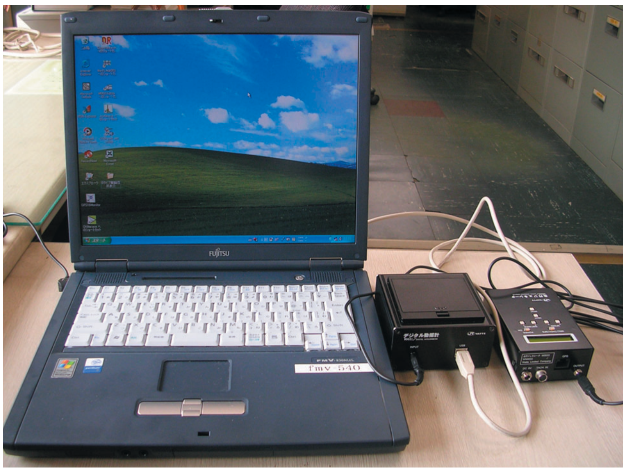


Fig. 1 Component parts of the ride comfort evaluation system

Fig. 3 Running motion data generator

Development of a Totally Enclosed Permanent Magnet Synchronous Motor

Minoru KONDO
Assistant Senior Researcher, Drive Systems, Vehicle Control Technology Division

1. Development objectives

Traction motors for electric trains are generally equipped with a ventilation cooling system to save weight and boost motor power outputs. Unfortunately, the ventilation brings outside dust and dirt into the motor, necessitating periodic disassembly and cleaning of the motor. The ventilation system is also a source of noise. If, however, the traction motor is totally enclosed, it will not need such disassembly or cleaning, and will emit less noise. Enclosing the motor, however, would lead to the need for a new type of cooling structure and greater efficiency, to prevent the temperature of component parts from rising above acceptable limits while ensuring sufficient motive power.

We therefore examined the possibilities of a highly efficient permanent magnet synchronous motor (PMSM), and first developed a totally enclosed prototype with a continuous rated output of 140 kW. We then examined the possible use of such a motor for a next-generation train for suburb-to-city transit, and developed a traction motor with a far higher continuous rated output of 235 kW. (Fig. 1)

2. Prototype motor design

Development of the more powerful motor targeted a maximum train speed of 140 km/h, a high acceleration rate of 2.6 km/h/s, and a train set configuration ratio of 1 motorized car to 2 trailers. For these reasons, we targeted an increase in the continuous rated output to 235 kW. In addition, because the new motor would be used on narrow-gauge (1067mm) track, we designed a totally enclosed PMSM that would meet space restrictions, while still ensuring the targeted output.

If a PMSM is to be used to power an electric train, the induced voltage from the magnet must not exceed acceptable limits. We therefore designed the rotor of the motor so that it would increase the magnetic saliency to generate the reluctance torque (see Fig. 2). This enables the reduction of the induced voltage while preventing an increase in electric current.

Fig. 1 235kW Totally-enclosed PMSM

We also employed a sensorless control system to eliminate the need for a rotor position sensor. This ensured enough space for the greater output, greater reliability and lower cost.

3. Test results

We first performed temperature rise tests and verified that the prototype motor could achieve the targeted output within acceptable temperature limits. From the test results, we calculated an efficiency rate of about 97%, considerably higher than the approximately 92% of a conventional traction motor.

We also measured noise emitted from the prototype motor when in stationary operation, and determined that noise levels were lower than those of a conventional induction motor (see Fig. 3). The ventilation fan and other components of a conventional self-ventilated traction motor emit noise that increases with rotation speed. On the other hand, measurement results indicated that, by totally enclosing the prototype motor, it is possible to reduce noise levels far below those of a conventional motor operating in the high-speed range.

4. Conclusions

We found that mounting a permanent magnet synchronous motor within a totally enclosed structure makes it possible to reduce maintenance, cut noise emissions and save energy, while still maintaining the motive power of a conventional traction motor. The results also indicated a continuous rated output of 235 kW, even in the restricted space available for narrow-gauge track operations. The new traction motor technology is now being used in U@tech test vehicles of JR West for tests on actual rolling stock equipped with the totally enclosed PMSM, with a view to using this new type of motor in commercial operations.

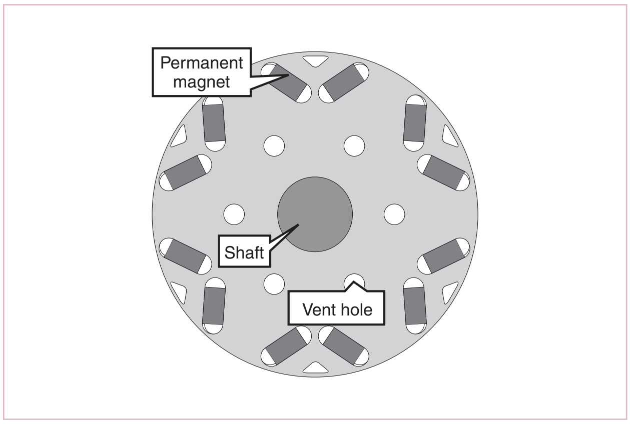


Fig. 2 Sectional view of the rotor

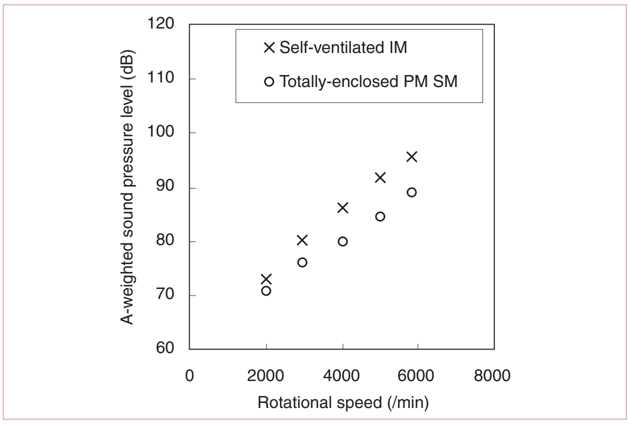


Fig. 3 Noise measurement results

Polymer Wall to Protect Underground Structures from Earthquakes: Development and Installation

Yoshitaka MURONO
Senior Researcher, Earthquake & Stractural Engineering, Structures Technology Division

1. Polymer anti-seismic piling

The newly developed 'polymer seismic isolation method' involves the construction of polymer walls on both sides of underground structure in order to reduce the seismic action transmitted from the surrounding ground onto the structure. The stiffness of the polymer material should be about 1/10 to 1/100 that of the surrounding ground. This method is not intended to prevent or control the seismic ground deformation itself, but to isolate structures from seismic forces transmitted from the surrounding ground. See Fig. 1.

The polymer seismic isolation method has the following advantages over conventional anti-seismic methods (such as the steel jacket method):

i.) The polymer reduces the seismic force transmitted from the ground, thereby reducing relative deformation of the structure. A steel jacket, for example, would reinforce only one part of the structure, whereas the polymer reduces the cross-sectional force on all structural parts, improving the seismic performance of the structure.

ii.) Use of a polymer with a stiffness of one-tenth of the sheer wave velocity of the surrounding ground will, depending on certain conditions, reduce the sheer force by up to half.

iii.) The polymer is installed from above ground, near a cut and cover tunnel, so the work can be done at any time, not just during the night when trains are not running. This shortens the retrofitting period, thereby reducing cost considerably.

iv.) There is no need to drill holes in the existing concrete structure.

2. Seismic reinforcement of an existing subway station

(1) Design calculations

A plan was drawn up to construct a four-story building directly above Nakagawa Station on the Blue Line operated by the Transportation Bureau of the City of Yokohama. The station had been constructed in a cut and cover tunnel. However, a seismic performance assessment of the existing tunnel discovered that the sheer force caused by a possible earthquake could exceed the bearing force capacity of the sidewalls and center pillars. The center pillars could be reinforced adequately by the steel jacket method, but there was no conventional effective method to reinforce the sidewalls. The decision was therefore made to install polymer anti-seismic piling.

Sheet piles had been left in place after the existing cut and cover tunnel was con-structed, and the area available for anti-seismic measures was narrow. Taking into account these con-struction con-straints, numerical analyses were carried out in order to deter-mine the properties of the polymer iso-lation wall and its position. The analyses led to the decision to use a polymer material with a rigidity of approximately one-tenth of the sheer wave velocity of the surrounding ground. The analyses also determined that the polymer isolation piles (columns) should be arranged as indicated in Fig. 2. These decisions were reached after considering the existence of the sheet piles and other structural components left in place after the original construction, and after it was determined that the installation of polymer piling at a certain distance from the tunnel walls would still be effective.

The seismic performance of the retrofitted structure was evaluated under these conditions. The evaluation indicated that the relative deformation would be reduced by 30%, and that the sheer force on the sidewalls would remain within safety levels even in the event of a major earthquake. Incidentally, the center pillars were reinforced by the steel jacket method.

(2) Installation

Retrofitting was conducted in February, March and April 2006 in these three phases:

i.) A small ground stabilization machine equipped with an auger screw was used to bore holes in the ground and remove earth.

ii.) Polyethylene bladders were inserted against the walls of the drilled holes and a PVA polymer liquid was poured in to fill the bladders, to make the polymer anti-seismic piles.

iii.) The top 2 meters of the holes were filled not with the polymer material but with a sandy soil. Fig. 3 shows part of the retrofitting process.

3. Future potential

Relatively serious earthquakes have struck different parts of Japan over the last few years, prompting the general public to show greater interest in anti-seismic measures. We expect the above-mentioned polymer seismic isolation method to contribute effectively to the reinforcement of existing cut and cover tunnels.

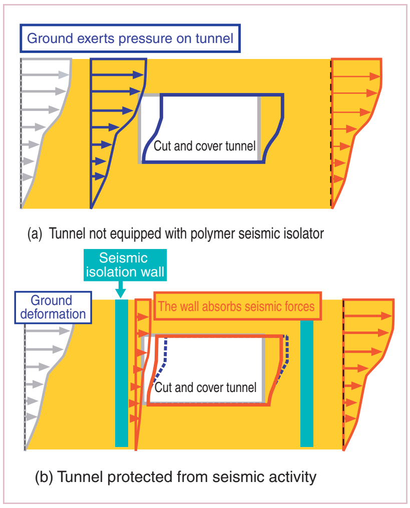


Fig. 1 Polymer seismic isolation method (conceptual diagram)

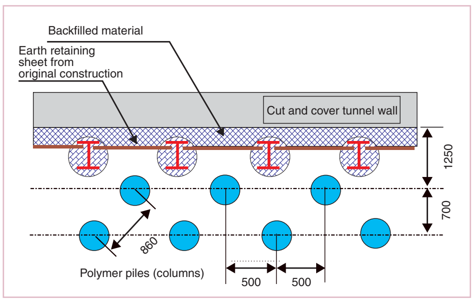


Fig. 2 Polymer seismic isolation method employed to retrofit Nakagawa Station (conceptual diagram)

Fig. 3 Preparing for installation

Smoothening the Sliding Surface of Overhead Rigid Conductor Lines to Reduce Contact Loss

Satoshi HARADA
Assistant Senior Researcher, Contact Line Structures, Power Supply Technology Division

A rigid conductor line is more reliable than a catenary wire because it is less likely to break as a result of abrasion. However, little elasticity is exhibited between a overhead rigid conductor line and pantographs, meaning that even a slight unevenness in the line can result in contact loss. Any arcing that accompanies the contact loss may result in undulating wear on the sliding surfaces. The undulating wear will further increase contact loss, leading to even more wear in contact wires and pantograph sliders. This phenomenon requires corrective action.

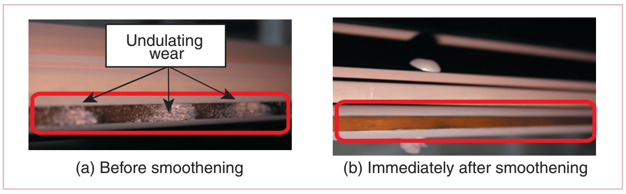
Unevenness exhibiting a variety of wavelengths may be found along the sliding surface of a contact wire under a rigid mount. One such unevenness is that seen between the long ear bolts used to attach the contact wire to the rigid mount. Another significant unevenness is seen at 200mm wavelengths when perpendicularly wound contact wire is used; this unevenness is presumably caused by the stretching machine when the contact wire was installed. On the other hand, when a sideways wound contact wire is installed, little unevenness at 200mm wavelengths is seen. Figure 1 indicates spectrum densities at the sliding surfaces of uneven contact lines attached to a rigid mounting soon after installation.

In many cases, the configuration of pantographs sliding under conductor lines where undulating wear occurs is like that shown in Figure 2: the distance between pantograph heads is 250mm, the distance between slider centers is 60mm, and a solid lubricant has been inserted between the sliders. With such a configuration, the solid lubricant has a tendency to ride up on uneven sections of the conductor line sliding surface, subjecting all four sliders to contact loss. The resulting arcing tends to cause part of the contact line to melt, and to cause wearing in the slider coming immediately after. This phenomenon will be repeated time after time, and the extent of the damage will depend on such factors as speed. The result will be undulating wear in wavelengths of 60mm, the same length as the distance between slider centers. To reduce contact loss arcing, the solid lubricant was removed from one of the pantograph heads. This did indeed control undulating wear in a catenary wire, but generally had little effect in the case of overhead rigid conductor lines.

Contact loss arcing exhibited on overhead rigid conductor lines can, however, be reduced by smoothening out the unevenness where undulating wear has occurred in the sliding surface. We therefore developed a grinding device (see Figure 3) that grinds the sliding surface to make it smooth. The device applies a grindstone at a fixed pressure to the sliding surface while grinding, and is equipped with a mechanism that tilts to adjust to flexures in the rigid conductor line. The device runs at a speed of about 4 km/h, continually grinding the sliding surface of the contact wire.

Figures 4 and 5 show the results of grinding the overhead rigid conductor line of a regularly operated railway line. The waveforms depicted in Figure 5 were observed on uneven sliding surfaces before smoothening, and on a regular basis during a period of 24 months after smoothening. Before smoothening, undulating wear occurred at wavelengths of approximately 60mm, but the grinding device smoothed out the sliding surface and, as Figure 5 shows, the undulating wear did not reoccur over time afterward.

Figure 6 shows the result of contact loss observations using a contact loss arcing detection method for the section that had been ground smooth. It was confirmed that, after smoothening, contact loss arcing was reduced. Using the device to smoothen out unevenness immediately after installation of contact wires can be even more effective in reducing contact loss on overhead rigid conductor lines.



(a) Before smoothening (b) Immediately after smoothening

Fig. 4 Sliding surface before and after smoothening

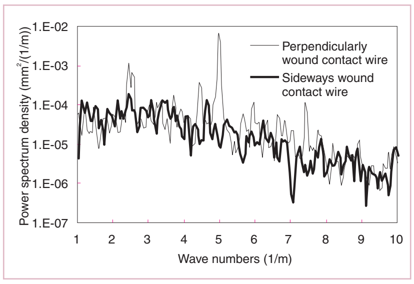


Fig. 1 Results of unevenness on the sliding surface of a overhead rigid conductor line

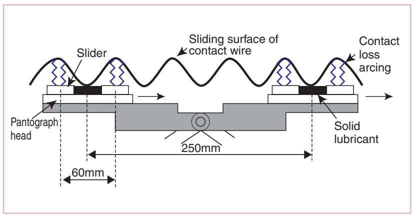
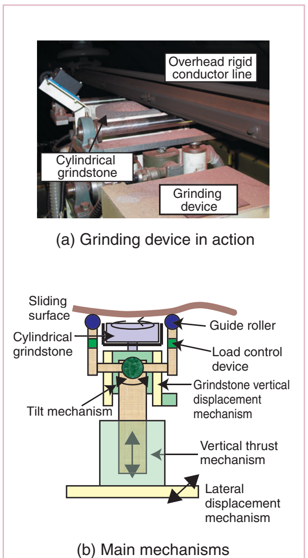


Fig. 2 Pantograph head configuration and contact loss arcing



(a) Grinding device in action

(b) Main mechanisms

Fig. 3 Salient features of grinding device

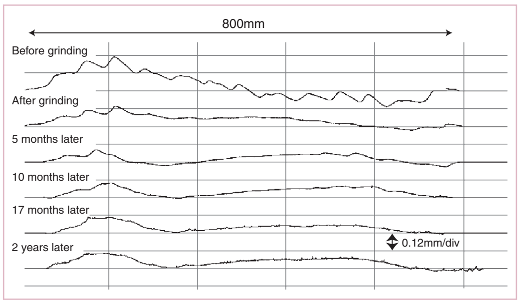


Fig. 5 Observed results of grinding of the sliding surface of an uneven overhead rigid conductor line

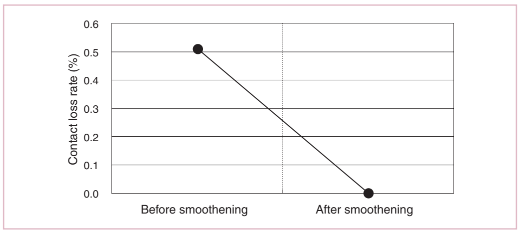


Fig. 6 Contact loss rate on a overhead rigid conductor line, before and after smoothening