Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN
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GENERAL INFOMATION

ARTICLES

Commercialising the Results of Research

Shinji KONISHI
Director, Marketing and Business Development Division

Every year the Railway Technical Research Institute (RTRI) obtains a number of excellent research results which can be applied to railway operation. Its research and development activities cover various fields, such as civil engineering, disaster prevention, rolling stock, electrical engineering, telecommunications, materials and ergonomics, etc.
RTRI has quickly commercialised most of these outcomes for use by customers, though some results require further work to arrive at practical applications.
To disseminate the technologies newly developed by RTRI and promote their more widespread use among railway operators and other customers, the Marketing and Business Development Division (MBDD) is now promoting commercialisation and on-contract-application of products developed by RTRI which have practical benefits. MBDD works in conjunction with the Research and Development Promotion Division and other R&D Divisions at RTRI.
Some research work is now conducted under contract to the government, railways, Japan Railway Construction, Transport and Technology Agency (JRTT) and other organizations, with the results utilized by the respective contractors.
MBDD arranges meetings for technology transfer and studies on specific topics, where it introduces RTRI's achievements that are useful for railway businesses. MBDD also exchanges opinions with customers, identifies the needs in the field and collects the necessary data, which are fed back to research divisions to determine new themes for research and development in the future.
Railways are now required to undertake development and improvement in various ways. These include running faster services and achieving manpower savings, the keywords being reliability (safety and stability), convenience (rapidity, comfort), economy (low costs) and harmony with the environment. As a result, the services to be carried out by railway staff have become extremely sophisticated, diversified and complicated. This suggests that railway companies may have a number of problems which are specific to their own management conditions, and these need to be solved by railway operators.
For this purpose, therefore, customers are kindly requested to draw on the expertise of experts at RTRI, who have high-level knowledge and technological competence.

Collaboration with the Rail Safety and Standards Board in the U.K.

Ryo SAWADA
Manager, R&D Planning, Research & Development Promotion Division

The Railway Technical Research Institute (RTRI) has been collaboration with the Rail Safety and Standards Board (RSSB) in the UK, consulting on the promotion of joint research, and discussing fundamental issues. As a result of this work, a memorandum with RSSB was concluded in October 2008. This is summarized below.

RSSB is an organization in the UK that is promoting leading activities in the research and evaluation of safety and in other fields based on the knowledge obtained from a number of accidents in the past.

The purpose of RTRI in concluding this agreement is to establish an organizational and collaboration relationship with RSSB to promote joint research and to exchange information, so aiming to foster research and development on safety evaluation and other themes.
To clarify the role and purpose of each party in promoting joint research, the two parties agreed the following two themes in different categories.

<1> "Joint research themes" to execute joint research in accordance with the role specifically assigned to each party.
<2> "Information exchange themes" to frequently exchange information between the two parties for the purpose of improving their technological competence.

The two parties shall complete research on these themes in two years and hold a joint meeting once every two years thereafter to report the research results.

Dr. N. Kumagai. Executive Director (Research and Development), RTRI, and Mr. A. Jack, RSSB, have been nominated as representatives of each party in regard to the promotion of the joint research.

The joint research started in October 2008 after the memorandum was concluded. As the first themes on "joint research" and "information exchange," the following two topics were chosen after prior negotiations between the two parties. The description within brackets represents the research division involved on the RTRI side.

○ Joint research
"Effect of human factors in the risk assessment and the method to classify human behaviors" (Human Science Division)
○ Information exchange
"Failure of wheel axle and ultrasonic flaw detection for hollow axles" (Vehicle Structure Technology Division)

In the future, the two parties will exchange information on their master plan for research and development and determine themes useful for both parties. Exchanging researchers will also be discussed in parallel.

Dr. N. Kumagai (RTRI) and Mr. A.Jack (RSSB)

Predicting Landslides a Few Months in Advance of Their Occurrence by Observing the Chemical Composition of Groundwater

Hiroyuki SAKAI
Senior Researcher, Biotechnology, Environmental Engineering Division

To provide customers with safe and comfortable rail services, long-term remote sensing technologies have been developed to protect railway lines against the consequences of abnormal climate activity such as heavy rainfall which can cause serious disasters on the ground, including landslides. Thanks to a technique using chemical sensors, ground disasters or landslides can be predicted a few months before they occur.

In recent years, climate has changed throughout the world, especially in Asia and Europe, resulting in changing patterns of rainfall. Thus, even in Japan, sudden, torrential falls of rain have been observed frequently during the last 10 years. Japan Railways (JR) provides railway services all over Japan, where over 50% of routes are located in mountains or on the coast with steep cliffs immediately behind the tracks. In the meantime, weather forecasting services have improved to such an extent that it is possible to estimate in advance when and where localized torrential rainfall will occur. In parallel, the relationship between precipitation and the risk of ground disasters including landslides has been confirmed. In this situation, however, the information from such sources warning us to be aware of possible ground disasters affecting railway tracks comes at short notice, mostly just before the incidents caused by heavy rainfall.

Furthermore, it is not always the case that engineers are standing by all the time watching for such disasters close to the location where the disaster occurs. Instead, they are typically some distance away from the site, and it would normally take at least one hour to visit the site for a check. So this traditional method of dealing with the problem is of no help to railway customers who may need to make alternative travel arrangements if their rail service is affected. To ensure that rail travel remains safe and that customers are protected from natural disasters, therefore, a long-term remote observation system is needed to predict the next occurrence of a ground disaster.

Basically, current technologies to predict ground disasters are all based on the method where the distortion or displacement of the ground is measured directly where it may affect structures or railway tracks. However, detection in this manner will give information only on the current movement of the ground or conditions just a few days prior to disasters. Since this method is effective only when a disaster is likely to occur imminently, it is impossible to organize alternative transport services in advance to avoid natural disasters. What is more important is to know more easily when such a natural disaster is likely to happen, or within how many weeks or months.

To overcome the lack of such information, which would not normally be available using conventional technologies for predicting disasters, an important technique has been developed involving the use of a chemical sensor, which has never been used before for ground disaster detection work. Chemical sensors or ion-selective electrodes can be used to monitor the chemical compositions of the groundwater seeping from the ground where landslides are anticipated. The groundwater contains inorganic ions that originate from soil particles in the ground. The concentration of the ions does not change while the ground remains stable. However, it changes when deep and virgin ground is distorted, resulting in the displacement of the surface ground, which leads to a landslide. Certain specific ions in the groundwater, therefore, indicate the possibility of a landslide by an increase in their concentration. The changes in concentration are more easily observable than when displacement is detected on the surface of the ground. This is because the groundwater seeps out from the ground continuously and rapidly. In contrast, the distortion inside the ground takes a long time to cause displacement of the surface. It turns out that the groundwater composition suggests the occurrence of a ground displacement event such as a landslide well before it occurs. Actually, the latest result showed that the increases in specific ion concentrations occurred four times, each time observing a ground displacement a few months thereafter, while the composition of the groundwater was being continuously monitored for 700 days with a prediction system at an inspection site on a JR service line. This is shown in Fig. 1.

Sensors used in this system are remotely controlled at a JR track maintenance office to give dispatchers and civil engineers information that may indicate the likelihood of natural ground disasters in the future. This is illustrated in Fig. 2. Once they receive this information, they can easily arrange for railway embankments or cuttings to be reinforced, find alternative routes for passengers and cancel train services. What is most important is to predict the occurrence of natural disasters easily well in advance of the event, but it is not essential to predict exactly when they will occur. By obtaining disaster information in advance, all arrangements can be made to protect rail services because sufficient time is available. Non-availability of information in advance will only surprise railroad operators. On the other hand, if the information is available, they will and can be prepared to ensure that safer, more reliable and comfortable transport services are available for customers with enough time guaranteed by the prediction system.

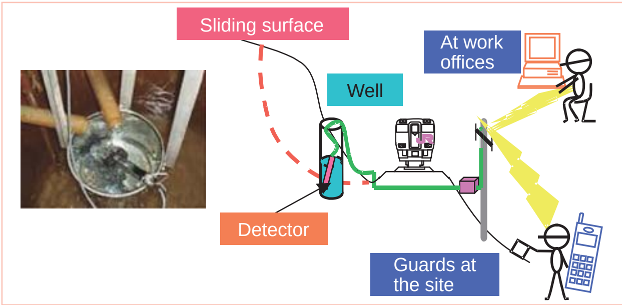

Fig. 1 The telecommunication system to successfully send information on the groundwater composition on demand to workers in charge of and responsible for train operation. The chemical sensor immersed in the groundwater in the well periodically determines the concentrations of ions in the groundwater. The signals from the electrodes are processed to save the data in a data logger, which are transmitted to the relevant workers through the public telecommunication service.

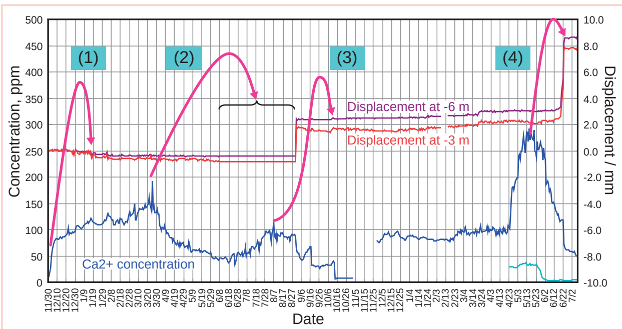

Fig. 2 Changes in the groundwater composition and ground movement

Improvement for Provision of Information upon Suspended Train Services

Kana YAMAUCHI
Assistant Senior Researcher, Ergonomics, Human Science Division

When train services suspended after accidents resulting in injury or death, or for other reasons, many passengers require the information concerning the resumption of services available as soon as possible. At present, however, it is not always possible to meet such requirements. The Railway Technical Research Institute (RTRI) is therefore currently under promoting a research to solve such a problem, as summarized in the following:

First, RTRI is studying whether the reaction of passengers and the use they make of the information changes when prospective information provided rapidly, even though it is uncertain. RTRI is also studying whether passengers react differently if the information is ambiguous to include different content.

Second, RTRI is discussing ways to support and improve the duties of the dispatchers and station staff members who transmit and convey appropriate information to passengers involved in suspended train operations. For this purpose, RTRI aims to improve various aspects of the software such as manuals for PA system and vocational materials for on-the-job training.

In the first part of this study, RTRI planned experiments to obtain data by accurately reproducing the scene at the station where passengers encountered with suspended train services. In these experiments, RTRI used audiovisual apparatus to demonstrate the situation at the station and the timing of the PA system of advisory information as a series of time events in a given scenario (Fig. 1); the test subjects were the information announced by acoustic means (Fig. 2).

In this study, RTRI adopted the following two different scenarios.

Scenario 1: Test subjects are provided initially with prospective information on the resumption of train services 10 minutes after the occurrence of the accident. They are then given information successively, including changes on the train schedule (new scenario)

Scenario 2: Test subjects were unprovided with information until the information on the schedule was almost definitive (conventional scenario).

For comparison, RTRI adopted the following two themes in Scenarios One and Two.

Theme 1: Usefulness of the information provided to passengers at stations

Theme 2: Timing to determine the action taken by passengers (taking an alternative route or waiting for the resumption of train services)

Regarding the theme 1, the number of passengers who judge that the scenario-1 is more useful is approximately three times that of the passengers who support the scenario-2 (Fig. 3). This means that even uncertain information is acceptable as significant, when offered rapidly.

Regarding the theme 2, when train services suspended due to an accident involving injury or death, the number of passengers who have not determined their actions 30 minutes after the occurrence of the accident is only 5% in the scenario-1 whereas the corresponding figure is 29% in the scenario-2.

In the second part of the study, RTRI implemented an interview of the dispatchers and distributed a survey questionnaire to the station staff belonging to a railway company (Company A) in the Tokyo metropolitan zone. As a result, it was evident that information on the resumption of train services generally transmitted unsatisfactorily, or passed on 10 minutes after the occurrence of an accident as recommended by Company A. It was also proven that the less railway employees evaluate the usefulness of non-definitive information for passengers, the less positive they are in transmitting the information.

To make employees, or information providers, of railway companies understand the concrete merits of providing information effectively and to reduce the number of complaints by passengers seeking to obtain information on the expected development of the situation after an accident, RTRI will provide "a PA system manual for use in abnormal situations" and "materials for on-the-job training."

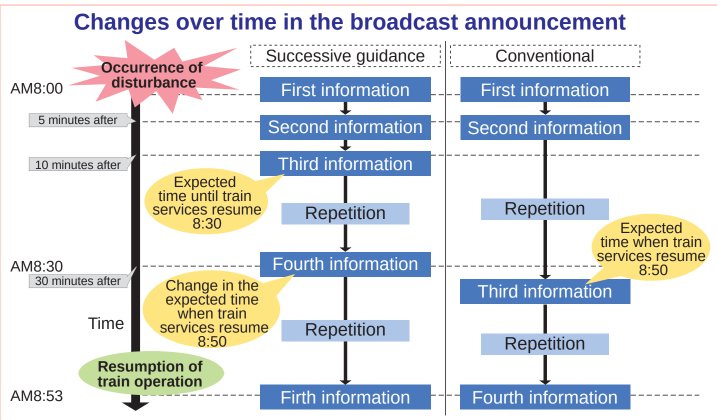

Fig. 1 An example of advisory information

Fig. 2 A view of an indoor experiment

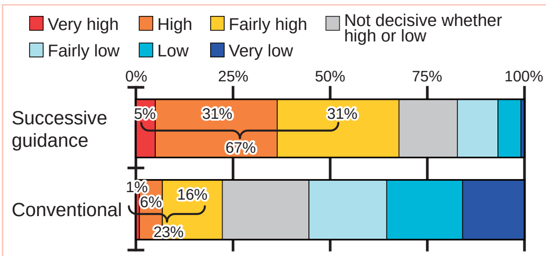

Fig. 3 Usefulness of the information provided at stations (evaluation of the scenario of an accident involving injury or death)

Development of a Cooling System for High-Temperature Superconducting Traction Transformer for Railway Rolling Stocks

Kazuya IKEDA
Senior Researcher, Cryogenic Systems, Maglev Systems Technology Division

Research and development work is in hand for a high-capacity pulse-tube cryocooler that is at the heart of a cooling system of superconducting traction transformers that supports an overhead line voltage of 25 kV on the Shinkansen (bullet train) lines. The requirements in the specification of the cryocooler provide for a cooling capacity of 1 kW or more at a temperature of 65 K, percent Carnot of 18% or more (Th=300 K). The development challenge to meet this specification is to reduce the weight of Shinkansen vehicles, the weight reduction being achieved by applying superconductivity to the coils of traction transformers which are some of the heaviest items of equipment on the vehicle. Regarding normal oil-cooled traction transformers that are currently mounted on Shinkansen trains, those mounted on the N700 series since April 2008 are the lightest design to date, with a mass-to-capacity ratio of 0.69. If the mass-to-capacity ratio is even lower than this value, the advantages of applying superconductivity to the coils will be achieved.

In the design of superconducting traction transformers, we have studied electric currents that can be expected to pass through wires, and masses of iron cores. As a result, provided that the AC loss becomes 1 kW or less, assuming capacity to be 4 MVA, there is a prospect that superconducting traction transformers offer an advantage over normal traction transformers in terms of their mass-to-capacity ratio, even if the mass of the cooling equipment for generating subcooled liquid nitrogen to replace the oil-cooling is added. Thus, the development of a small high-capacity cryocooler has become necessary.

The reason for selecting a pulse tube cryocooler is the belief that it will be easy to re-use the system based on the fact that on a natural circulation cooling system that is in contact with the pin pole type heat exchanger at the cold head of the GM cryocooler, absorption of small-scale head loads has been verified.

Furthermore, a reduction in the weight of the cryocooler can be expected as there is no displacer made of Bakelite.

Figure 1 illustrates a schematic diagram of the cooling system using a simplified pulse-tube cryocooler.

A prototype pulse-tube cryocooler that used an active-buffer for phase control achieved a cooling capacity of 1.19 kW at a temperature of 65 K, and percent Carnot of about 8.6%. The on-off valves between the compressor and the cryocooler, between the cryocooler and the active-buffer are not dedicated rotary valves, but are replaced by several electromagnetic valves connected in parallel for the purpose of the performance evaluation test.

In subsequent improvements, as the result that we have performed change of regenerator material configuration meshes, improvement in gas conductance (increase in the Cv values of electromagnetic valves, increase in the quantity of electromagnetic valves) in the above-mentioned circuit, the addition of a manifold buffer tank to the compressor high/low pressure circuit,

In subsequent improvements, we changed the regenerator material configuration meshes, improved gas conductance (increased the Cv values of electromagnetic valves and increased the quantity of electromagnetic valves) in the above-mentioned circuit, and added a manifold buffer tank to the compressor high/low pressure circuit. As a result, we were able to raise the percent Carnot up to about 13.4% without deterioration in the cooling capacity.

Figure 2 shows the enhancement of the percent Carnot.

Figure 3 is a real example of the pulse-tube cryocooler.

As a result of our work, we have confirmed that it is possible to meet fully the initial requirements specification by optimum design of the dedicated rotary valves.

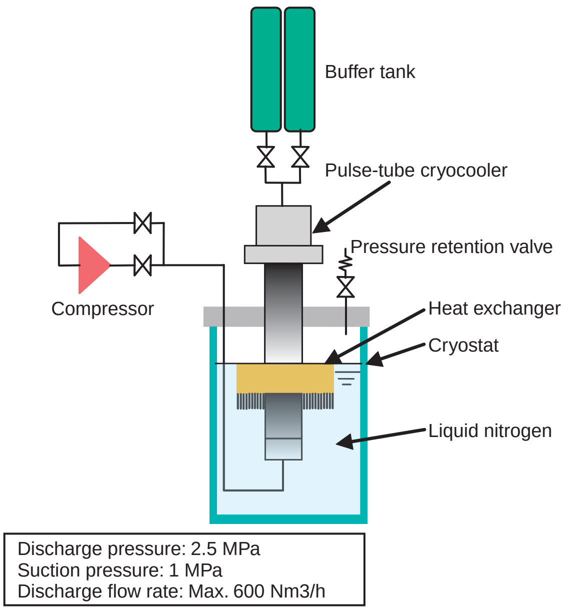

Fig. 1 Cooling system by pulse-tube cryocooler

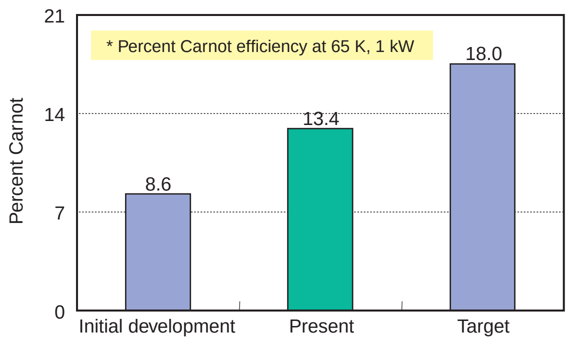

Fig. 2 Transition of percent Carnot

Fig. 3 Practical version of a pulse-tube cryocooler for a traction transformer

An Ultrasonic Flaw Detector for Hollow Axles of Narrow-Gauge Railway Cars

Kazunari MAKINO
Assistant Senior Researcher, Vehicle and Bogie Parts Strength, Vehicle Structure Technology Division

Hollow axles with an internal bore diameter of 60 mm are used for all Shinkansen cars manufactured in and after 1992. When the cars undergo maintenance, checks are made automatically for flaws using ultrasonic angle beams from the bore surface, as shown in Fig. 1. On the other hand, most of the narrow-gauge cars in Japan are equipped with solid axles, the inspection of which is inherently more difficult in terms of improving precision and automatic flaw detection. Based on the experience of using hollow axles on Shinkansen cars for 15 years or more, therefore, we developed hollow axles suitable for narrow-gauge cars and a prototype ultrasonic flaw detector for use with these axles. Figure 2 shows the concept of hollow axles for narrow-gauge cars. However, some narrow-gauge cars use axles with a journal diameter smaller than that of the Shinkansen cars, and these do not have sufficient space at the end of the axle where a cap is attached with bolts. To cope with this restriction, therefore, we designed the bore diameter of the axles for narrow-gauge cars to be 30 mm smaller than that of the Shinkansen cars. Flaw detection is performed from the bore surface of a hollow axle with a 30 mm bore diameter using a conventional probe having a built-in flat transducer, as shown in Fig. 3. Ultrasonic waves focus at a point inside the axle due to refraction at the bore surface and then disperse on the axle surface being inspected. In addition, the path length of ultrasound propagation increases to the extent that the bore diameter is smaller or the wall thickness is larger, which may cause flaw detection sensitivity to deteriorate. To compensate for this drawback, therefore, we designed and manufactured a special piezocomposite focal probe using a flexible piezocomposite transducer, as shown in Fig. 4. Figure 5 shows the ultrasonic flaw detector developed for hollow axles of narrow-gauge cars. By using this probe, we conducted a test to detect a number of artificial flaws cut on the surface of a model axle. As a result, we successfully detected rectangular flaws, with a length of 10 mm and a depth of 0.3 mm, at the wheel seat of the axle, and others, with a length of 10 mm and a depth of 0.15 mm, in the central part of the axle. This confirmed that the precision of flaw detection with this probe is equal to that hitherto obtained for axles of Shinkansen cars.

To increase the fatigue strength, induction hardening treatment is applied to axles for Shinkansen cars after the normal heat treatment (quenching and tempering) in the manufacturing process. In contrast, only the normal heat treatment is applied to axles for narrow-gauge cars. It is expected, therefore, that the fatigue strength may decrease when a bore is machined in the axles used for narrow-gauge cars. Hence, we performed a full-scale rotating bending fatigue test for a hollow axle, as shown in Fig. 6, with a diameter at the wheel seat of 209 mm and a ratio of the length of the central part to the diameter of 1.3, for narrow-gauge cars at nominal stress amplitude of about 80 MPa at the wheel seat. As a result, we were able to confirm that no fatigue cracks or conspicuous fretting corrosion occurred until the number of cyclic loadings reached 2.3 x 10^7. This proves that hollow axles have approximately the same fatigue strength as that of solid axles.

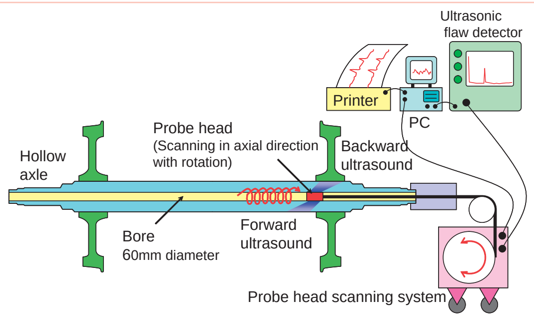

Fig. 1 Automatic ultrasonic flaw detector for hollow axles of Shinkansen cars

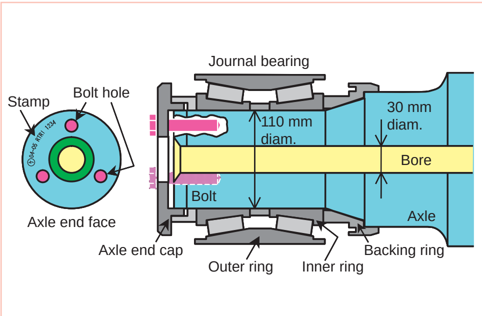

Fig. 2 A schematic view of a hollow axle for narrow-gauge cars

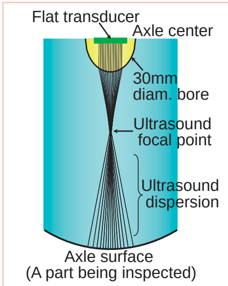

Fig. 3 A schematic view of ultrasound propagation oscillated with a flat transducer

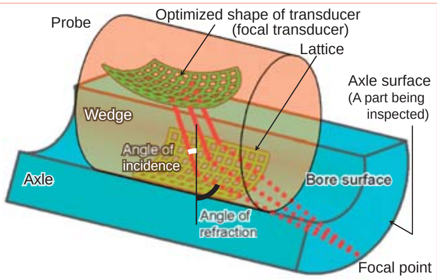

Fig. 4 Design concept for the piezocomposite focal probe

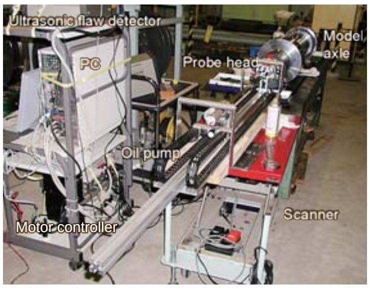

Fig. 5 Automatic ultrasonic flaw detector for hollow axles of narrow-gauge cars

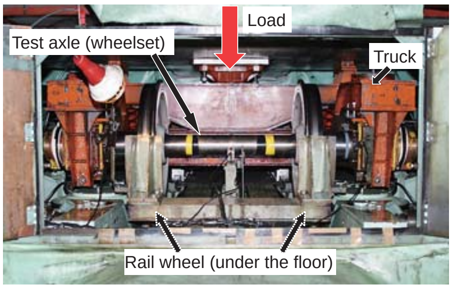

Fig. 6 An axle fatigue test plant