History and efforts for the future regarding inspection and repair based on rolling stock data for Shinkansen


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Summary

Last year, Tokaido Shinkansen celebrated its 50th anniversary. During this period, the rolling stock have been developed and also new technology has emerged in the areas of inspection and repair facilities for rolling stock. For the inspection and repair of Shinkansen rolling stock, we are devoting our efforts to establish a new organization for inspection and repair that allows full use of rolling stock data and have established an organization to record, transmit, and analyze abundant data obtained from the vehicles. By making use of the rolling stock data, it is possible to more efficiently organize inspection and repair works as well as improve the safety and stability of transportation.

This article describes the establishment of the system for obtaining and analyzing rolling stock data, track records regarding the rolling stock data analysis, and the new method of use of the data.

1. Introduction

The current conditions and problems in the inspection and repair of Shinkansen rolling stock are as follows: For Tokaido Shinkansen rolling stock, currently four categories of regular inspection and repair works, i.e. operation inspection, regular inspection, bogie inspection, and general inspection, are conducted according to ministerial ordinances and notices.

As the primary problem in the current inspection, it is pointed out that the decrease of the number of failures in rolling stock has leveled off. Figure 1 shows the progress of the number of failures. The number of failures decreased year by year until 2006 due to the development of rolling stock and technology for inspection and repair. However, it has leveled off after 2006 and no more reduction is achieved (Figure 1).

The secondary problem is that a lot of staff are still required for inspection works. Most of the regular inspection work that is currently conducted consists of operation and condition checks that are manually performed and requires a lot of working staff. Furthermore, the number of inspection and repair works are increasing because new functionality such as carbody tilting and reserve brakes in front-end cars are introduced while the rolling stock have been developed from the 700 series to the N700 and N700A series.

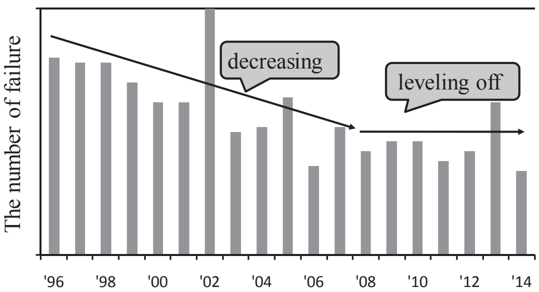

Fig.1 The number of failure ('96～'14)

Because it is considered that the organization for inspection and repair should be drastically re-established to solve the problems described above, we have promoted the use of rolling stock data. To establish a new organization for inspection and repair, we aim to add rolling stock data analysis as the “inspection in lines” to “inspection at a point” in conventional regular inspection to establish “inspection for points and lines”.

2. Establishment of the rolling stock data acquisition system

The term “rolling stock data” refers to data that indicates the conditions of the devices in the operating rolling stock. The targeted devices for data acquisition include the ATC, bogie, carbody inclination, side sliding door, air conditioner, brake, brake output control device (BPG), and electric circuit. The data regarding vibration, temperature, electric current, and operation time can be obtained for these devices. The equipment for recording the data has been gradually introduced to allow to identify the conditions of the running rolling stock by recording and analyzing the information of the devices listed above.

2.1 Development of the on-board data recording device

The forerunner of data recording functionality was the 300 series rolling stock introduced in 1992. The 300 series was capable of recording the rolling stock data for some of the devices such as the BPG. The 700 series introduced in 1999 was able to record data for various devices at once by using monitoring equipment. The data items recorded in the monitoring equipment are significantly increased in the N700 series introduced in 2007 to allow the recording of more rolling stock data.

Furthermore, new data recording equipment is introduced in the N700A series that is put into operation in 2013, therefore it is possible to record data for all devices that are connected to the monitoring equipment in a fine sampling cycle of 200 ms. Thanks to such development of recording equipment, the amount of recorded rolling stock data is increasing dramatically and has reached the level of 5 GB per train set a day (Figure 2).

2.2 Development of the system for transferring the data to wayside

The data recorded on board are transferred to wayside as described below: In the 300 series for which the rolling stock data recording was initially introduced, it was required to connect a personal computer to the target devices to read out the data. In this method, the chance to read out the data was limited and it took a long time to read out the data because some extra work such as removal of the lid on the opening to connect the computer was required. Therefore a system that allows to automatically transfer the data recorded

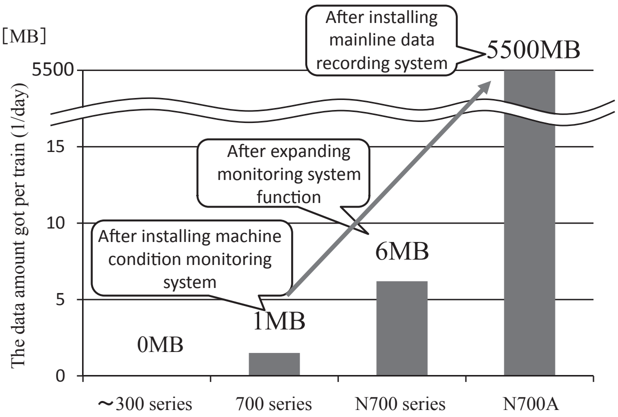

Fig.2 The amount of rolling stock data available

on board via the SS radio was introduced in the 700 series. The abbreviation "SS" represents the "Spread Spectrum" method that sends radio waves which transfer the data signal by distributing it on a wide range of frequencies. The SS radio is characterized by good resistance against noise and interference and superior in confidentiality. Therefore it became possible to transfer the data recorded on board by installing the SS radio transmission device on board and reception facilities in the car depot. In the N700 series rolling stock, to cope with the increase of the amount of recorded data, data is now transferred at a speed of 11 Mbps thanks to the high transmission speed of the SS radio (Figure 3).

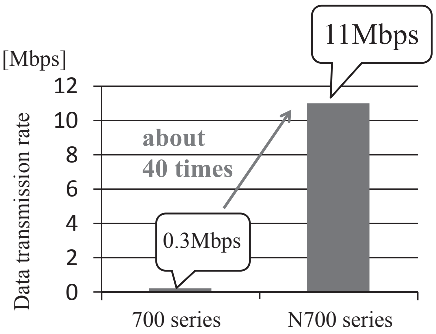

Fig.3 Increase of SS radio transmission rate

2.3 Establishment of the data storage and management system

The Advanced Rolling stock Information management System (ARIS) has been put in operation since 2003 to store and manage the recorded and transferred data. Thanks to ARIS, it became possible to centrally manage the rolling stock data to allow to search and retrieve data that has been extracted in various places. Therefore the use of the data has been dramatically improved.

3. Establishment of the rolling stock data analysis system

As a result of the efforts described above, it became possible to acquire huge rolling stock data and use them in the site. However, because the amount of acquired rolling stock data is enormous and it is virtually impossible to manually analyze all the data, we have advanced the development of both the physical infrastructure and the operation organization.

For the physical infrastructure, we developed and introduced the system that automatically analyzes the enormous data. The ATC chart analysis equipment developed in 2006 is the forerunner of the analysis system. This equipment automatically detects abnormalities such as over-speed and wheel slip / slide based on the ATC chart record. In 2007, monitor record analysis equipment was developed to allow to automatically detect abnormalities based on the data recorded in the monitoring equipment. Along with the equipment described above, the carbody inclination analysis equipment was developed to detect failure in the carbody inclination function by using the carbody inclination data for all train sets and curved sections to check the integrity of the carbody inclination system that was initially installed in the N700 series. In 2012, the bogie vibration detection device was developed to allow to automatically detect failure in the rotary driving system by analyzing the vibration data regarding the bogie. Thanks to this device, it is allowed to implement the analysis and check function on board for continuous monitoring of failure in the bogie. It is considered to be the analysis device with the current highest level of functionality. This device is beginning to be introduced in the N700A series. Along with the development of the hardware that composes the analysis system, we have established an operation organization by introducing a dedicated group of staff in the site for analysis. The group is engaged in finding signs of possible failure in the enormous rolling stock data that is obtained daily and instructing the car depot to conduct investigation and/or repair to prevent failure from occurring.

4. Track record of the rolling stock data analysis

The following describes the results with successful track records obtained from the effort to make use of the data listed above.

4.1 Failure prevention by detecting signs of a failure

Thanks to the rolling stock data analysis, it has become possible to identify many types of failure by detecting signs of failure in the precursor phase and successful results have been obtained in prevention of failure. For example, favorable results are obtained in the following three cases.

At first, there is a rolling stock failure that is called "un-release of braking". We developed a method to find a sign of un-release of braking in the data regarding the brake pressure to detect the omen of the failure. Thanks to the method, the occurrence of un-release of braking has been reduced (Figure 4). 6 cases of un-release of braking occurred in the period from 2009 to the beginning of 2010. However, the number of cases has decreased to zero after the method was introduced.

Next, the following describes the case of failure in the air conditioner. We developed a method to detect the omen of failure by analyzing the temperature controlled by the air conditioner. Specifically, we established a procedure to monitor the temperature setting and the actual cabin temperature and conduct inspection in the operating vehicle and the required repair works if any irregularity such as poor reaction is found. For example, there was a case in which poor air conditioning performance was found in the data analysis for a train set, and faulty wiring related to the air conditioning system was identified as the cause of the malfunction. In this case, the failure was prevented by taking an appropriate measure after the cause was identified. The temperature control function of the air conditioner is managed by such a procedure for

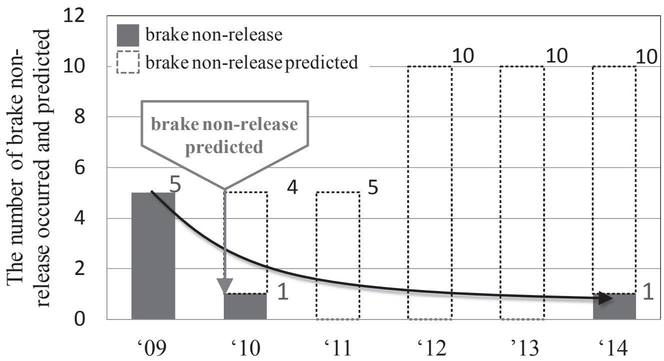

Fig.4 The number of brake non-release and prediction of the phenomenon

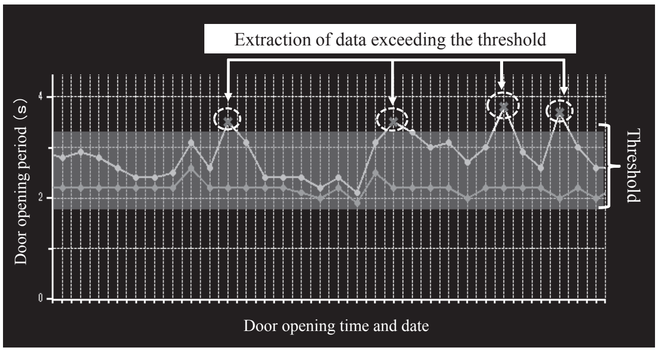

Fig.5 Side sliding door data analysis

all train sets.

Lastly, the following describes the case of failure in the operation of the side sliding door. We developed a method to detect the omen of failure in the operation of the side sliding door based on the analysis of the data for the side sliding door such as the opening/closing condition and the time required for opening/closing the door (Figure 5). As a result, a foreign object that might cause malfunction to the door was found in some cases.

Thanks to the methods that have been developed for detecting the omen of various failures as described above, more than 400 cases of malfunctions were found in the year of 2013 as shown in Figure 6 and the vehicle failures were prevented.

4.2 Verification of the equipment integrity

The correct functionality of the devices such as the ATC and brake equipment has been verified by using the rolling stock data. The ATC chart analysis equipment has analyzed the data corresponding to approximately 500 million lines to verify the integrity of the ATC system since its introduction in 2006. The carbody inclination analysis equipment has verified the integrity of the inclination function for all the train sets and curved sections. In addition to that, it has been allowed to check the integrity of the bogie by introducing bogie vibration detection equipment.

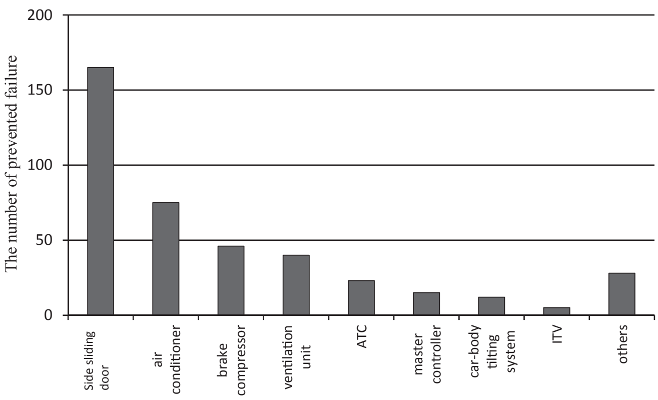

Fig.6 The number of the failure prevention by data analysis ('13)

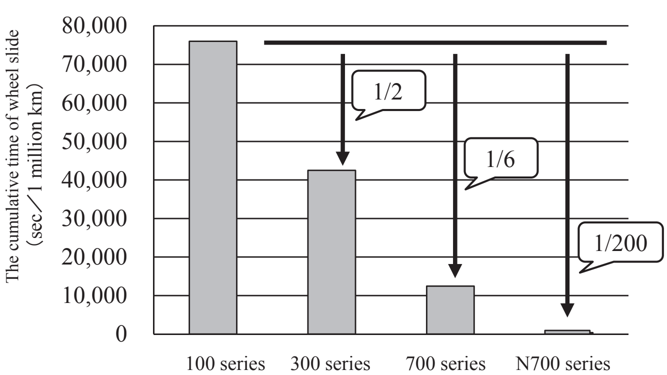

Fig.7 Decreasing wheel slide by anti-skid measure

4.3 Feedback for design

As an example of the case in which the result of the data analysis is fed back to the design, the following describes the case of introduction of a mechanism to detect wheel slip. In this process, the error in the location of the train was calculated based on data from the on-board ATC and wayside transponder and then the cases in which the error was significant were analyzed. Using the findings obtained in the analysis, a method to detect and control wheel slip by comparing the data of the slipping axle and that of the non-slipping axle has been developed and introduced in the N700A series.

Next, the following describes the effort to control wheel skid. As in the case of wheel slip, it has been allowed to identify the conditions of a skid in detail by analyzing enormous rolling stock data. Using the findings, the occurrence of skid has been significantly reduced due to the optimization of the braking load ratio, improvement of the skid control method, and improvement of the control of ceramic jetting. Thanks to the measures mentioned above, in the N700 series, the occurrence of skid has been reduced to approximately 200th of that for the 100 series (Figure 7).

5. New use of the rolling stock data analysis

5.1 Use in regular inspection

While the rolling stock data analysis has been further deeply developed, new use of data analysis has emerged. Use in regular inspection is one of them. The merits listed below are expected to be achieved by replacing a part of work in regular inspection with rolling stock data analysis:

① The accuracy of inspection is expected to be improved because verification can be conducted for all operations while the train is running on the main line rather than checking the operation only once in the regular inspection.

② The time required for regular inspection is expected to be reduced by replacing some inspection works such as operation checks and visual inspection manually conducted by staff with data analysis.

As an example of such an effort in our company, the following introduces the operation test for the side sliding door in the regular inspection. The operation of the side sliding door was checked by manually opening and closing the door in conventional regular inspection. However, a method has been established to conduct inspection of the side sliding door by analyzing the data such as the time required to open / close the side sliding door during operation on the main line. This new method allows not only to significantly increase the inspection frequency but also to reduce the time of inspection by approximately 10 minutes per regular inspection.

5.2 Application for optimization of parts replacement cycle

Optimization of the parts replacement cycle is another example of the new use of the rolling stock data analysis. Some of the parts used in the rolling stock are replaced before they deteriorate sufficiently according to the replacement cycle recommended by the manufacturer. It becomes possible to identify the optimum replacement cycle for such parts by determining the level of deterioration due to operation and/or secular change by conducting rolling stock data analysis. For example, elongation of the replacement cycle is achieved for the relay used for the carbody inclination control device. The carbody inclination control device controls the inclination by switching ON/OFF the (large-, medium-, and small-sized) three solenoid valves. Because the life of the relay that operates the solenoid valves depends on the number of operations of the solenoid valves, the data regarding the number of operations were obtained and analyzed. As a result, a cost reduction of approximately 100 million yen per year has been achieved by elongating the replacement cycle to an appropriate length for the relay used to control the large- and medium-sized solenoid valves of which the number of operations is small.

6. Conclusion

In this article, we introduce the history and effort for the future regarding inspection and repair based on the rolling stock data analysis for Shinkansen rolling stock. Although the inspection and repair of Shinkansen rolling stock has been conducted based on the idea of "inspection at a point", it is required to establish the organization for the "inspection for points and lines" that uses the rolling stock data analysis to conduct inspection and repair more safely and efficiently. Therefore we have developed and established an organization to record, transfer, and analyze the enormous data obtained from the rolling stock. As a result of these efforts, the rolling stock maintenance based on the data analysis is integrated in the inspection procedure and various successful track records have been achieved.

Tokaido Shinkansen celebrated its 50th anniversary in 2014. During this period, the rolling stock have been developed and also new technology has emerged in the area of inspection and repair facilities for the rolling stock. Furthermore, the number of staff employed after JR group was established is increasing and the circumstances have been considerably changed. Against the background in which the role and position that Tokaido Shinkansen is expected to take becomes more important while the Chuo Shinkansen project is proceeding towards commercial operation, to take further steps towards innovation, we are aiming to develop the required facilities to establish new organization for inspection and repair that more widely uses rolling stock data.

[Reference]

1) Hitoshi Okabe, Masahiro Suzuki, and Hidenori Hokari: Functionality improvement in management system for inspection and repair of Shinkansen rolling stock, JREA, Vol. 55, No. 11, pp. 44 - 47, 2012

NEWS

○The Railway Technical Research Institute Commences Research on the Utilization of Information concerning Seabed Seismometers to an Early Warning Earthquake Alarm System for Railways

The Railway Technical Research Institute has commenced research on the utilization of information concerning seabed seismometers to an early warning earthquake alarm system that will enable a train to stop more rapidly in the event that a large seabed earthquake occurs, thus realizing additional railway safety. Aiming at the development of this system, since July 2014 we have been engaged in joint research with the National Research Institute for Earth Science and Disaster Prevention (NIED), and in September 2015 we commenced joint research with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

The system in its present form utilizes information concerning rocking of a train which is captured by a land-based seismometer. This information is used to emit an alarm, causing a train to stop or decelerate. Amidst this research, NIED, JAMSTEC, and others are promoting the upgrading of seabed seismometers, so we commenced our research using information acquired from these organizations with a view to enabling an alarm to be emitted at an earlier timing.

A seabed seismometer differs from a land-based seismometer in respect of the installation environment and the installed condition. We decided to commence joint research with both of the aforementioned research organizations owing to the necessity of carrying out various studies in advance, aiming at utilization of information. Concretely, we will obtain a grasp of the characteristics of information that utilizes data recorded in a seabed seismometer, and carry out research concerning appropriate data processing methods. In addition, we will carry out development of concrete alarm processing methods and information transmission methods intended to ensure that the abovementioned system outputs an alarm without fail.

As is also exemplified by the Great East Japan Earthquake which occurred in March 2011, a massive earthquake that is generated on the seabed causes major damage to railways as well. At present, there are fears that a major earthquake will occur in the Nankai Trough in the near future.

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NEWS

○The Opening of the Rolling Stock Factory whose Construction in Britain was Promoted by Hitachi

This is a British Rail project that was actively promoted by Hitachi, Ltd. The opening ceremony for the railway rolling stock factory, whose construction in Durham County in the central part of Britain had been promoted by Hitachi Rail Europe, a British railway system project company, took place on September 3 and was also attended by Prime Minister Cameron. From next year, the new factory will start full-fledged production of the Class 800 series of new high-speed railway rolling stock.

In 2012, Hitachi was entrusted with the manufacture of 596 cars and also rolling stock maintenance work, concerning high-speed urban railways in Britain. Next, in 2014, we received additional orders for rolling stock. Concretely, a special purpose company called Agility Trains, which was established as a joint venture between Hitachi and a British corporation, received orders for 497 cars. Thus, together with the existing contracted volume, we will deliver a total of 866 Class 800 cars (122 train sets).

British Rail intends to employ the Class 800 rolling stock on two lines, namely the East Coast and Mainline which extends about 700 km from London to the north, and the Great Western Mainline which extends about 300 km westward. The rolling stock is designed to run at a maximum speed of 200 km/h, and two kinds of train sets, namely a 5-car train set (standard capacity approx. 300 persons) and a 9-car train set (standard capacity approx. 600 persons) will be manufactured.

The new factory has a floor area of 43,000 m2 and is equipped with rolling stock manufacturing and training facilities.

At the opening ceremony, a time capsule containing a model of the class 800 series and also digital data of pictures of trains drawn by children was installed in the factory. As representatives of the British government, Prime Minister Cameron and Patrick McLoughlin, Secretary of State for Transport, attended to celebrate the completion of the new factory.

In his speech, the British Prime Minister said, "The huge investment made by Hitachi is an indication of the trust that Hitachi has in the British economy. I hope that the new factory will not only create new employment opportunities and greater convenience for railway users, but also contribute to the strengthening of the necessary infrastructure for realizing further growth of the British economy." Hiroaki Nakanishi, Chairman and CEO at Hitachi indicated his determination by saying, "I am proud to say that we were able to construct this new factory in Britain, which is the birthplace of railways. By combining the manufacturing technology of Japan and Britain, Hitachi will continue to make greater efforts to ensure that the British side retains the initiative."

Selected from Kotsu Shinbun Newspaper