RI2020-2

RAILWAY SERIOUS INCIDENT INVESTIGATION REPORT

Vehicle damage, Suminoe Vehicle Inspection Division, Nankai Electric Railway Co. Ltd.

November 26, 2020

The objective of this report on the investigation for the railway serious incident, conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to contribute to prevent a railway accident, etc. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairperson
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

Railway Serious Incident Investigation Report

Railway operator: Nankai Electric Railway Co., Ltd.

Incident type: Vehicle damage, railway serious incident related with "the situation that malfunction, damage, destruction, etc., hindering the safety of the train operation in the running gears, brake gears, electric devices, coupling devices, train protection system, etc., of the vehicle occurred" stipulated in Item 8, Paragraph 1, Article 4 of the Ordinance on Report on Railway Accidents, etc.

Date and time: About 00:10, August 24, 2019, when the crack in the traction motor support was found.

Location: Suminoe Vehicle Inspection Division, Osaka City, Osaka Prefecture, where the crack in the traction motor support was found.

October 26, 2020

Adopted by the Railway Committee, the Japan Transport Safety Board

Chairperson	TAKEDA Nobuo
Member	OKUMURA Fuminao, Chair
Member	ISHIDA Hiroaki
Member	KAKISHIMA Yoshiko
Member	SUZUKI Mio
Member	NIITSUMA Mihoko

SYNOPSIS

<SUMMARY>

On Friday, August 23, 2019, the outbound 241 train "Rapi:t β41", composed of 6 vehicles started from Namba station of Nankai Main Line bound for Kansai Airport station of Nankai Electric Railway Co., Ltd., departed from Namba station of Nankai Main Line on schedule at 18:00. While the train was running between Sakai station and Kishiwada station, the conductor noticed the sound as metals were rubbing each other from the coupling part between the 2nd and the 3rd vehicles, *hereinafter, the left and right are based on the running direction of the outbound train and the vehicles etc., are counted from the outbound direction*. After that, while the train, which had arrived at Kansai Airport station and turned back as the inbound 250 train bound for Namba station, was running, the same conductor confirmed the similar sound from the coupling part between the 2nd and the 3rd vehicles

between Kishiwada station and Sakai station. Therefore, the conductor reported the occurrence of abnormal sound to the dispatcher in the transport dispatcher's office using the train radio. The dispatcher sent two vehicle inspection staffs to Izumisano station to get on the train, which had arrived at Namba station and turned back as the outbound 249 train bound for Kansai Airport station. The vehicle inspection staffs checked the status of the vehicles, but no abnormality was found. Therefore, the dispatcher instructed to check the vehicles after finished the operation of the day.

After finished operation of the day, when the vehicle inspection staff checked the vehicles again in the Suminoe Vehicle Inspection Division, the crack of about 140 mm was found on the backside of the traction motor support of the 1st axle of the 2nd bogie of the 2nd vehicle, at about 00:10 on August 24, 2019.

<PROBABLE CAUSES>

It is highly probable that this serious incident was caused as the crack, which was generated in the welded part between the cross beam of the bogie frame of the vehicle and the reinforcing rib on the backside of the traction motor support, propagated due to fatigue and reached the outer surface.

It is highly probable that the crack was generated in the welded part between the cross beam and the reinforcing rib on the backside of the traction motor support, because the welding defect was created, as the groove processing had not been performed when the bogie manufacturer attached the reinforcing rib to the backside of the traction motor support, and the crack had generated from here as the start point.

It is probable that the groove processing was not carried out related with the fact that the workers in the welding work site did not know that the groove processing should be implemented, because there was no description about the grooving in the work plan issued by the bogie technical management office of the bogie manufacturer submitted to the welding work site, where the groove processing is performed, and there was no definite work instruction.

Furthermore, the place where the crack was generated had not been designated by the company as the important place to be inspected after implemented the reinforcement, and the magnetic particle inspection was not conducted, therefore, it is likely that the crack could not be found even if the crack had already generated at the time of the periodic inspection.

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Attached Materials

1. PROCESS AND PROGRESS OF THE RAILWAY SERIOUS INCIDENT INVESTIGATION

1.1. Summary of the Railway Serious Incident

On Friday, August 23, 2019, the outbound 241 train "Rapi:t β41", composed of 6 vehicles started from Namba station of Nankai Main Line bound for Kansai Airport station of Nankai Electric Railway Co., Ltd., departed from Namba station of Nankai Main Line on schedule at 18:00. While the train was running between Sakai station and Kishiwada station, the conductor noticed the sound as metals were rubbing each other from the coupling part between the 2nd and the 3rd vehicles, *hereinafter, the left and right are based on the running direction of the outbound train and the vehicles etc., are counted from the outbound direction*. After that, while the train, which had arrived at Kansai Airport station and turned back as the inbound 250 train bound for Namba station, was running, the same conductor confirmed the similar sound from the coupling part between the 2nd and the 3rd vehicles between Kishiwada station and Sakai station. Therefore, the conductor reported the occurrence of abnormal sound to the dispatcher in the transport dispatcher's office using the train radio. The dispatcher sent two vehicle inspection staffs to Izumisano station to get on the train, which had arrived at Namba station and turned back as the outbound 249 train bound for Kansai Airport station. The vehicle inspection staffs checked the status of the vehicles, but no abnormality was found. Therefore, the dispatcher instructed to check the vehicles after finished the operation of the day.

After finished operation of the day, when the vehicle inspection staff checked the vehicles again in the Suminoe Vehicle Inspection Division, the crack of about 140 mm was found on the backside of the traction motor support of the 1st axle of the 2nd bogie of the 2nd vehicle, at about 00:10 on August 24, 2019.

1.2. Summary of the Railway Serious Incident Investigation

1.2.1. Organization of the Investigation

The serious incident is "the situation that malfunction, damage, destruction, etc., hindering the safety of the train operation in the running gears, brake gears, electric devices, coupling devices, train protection system, etc., of the vehicle occurred", *i.e.,* "vehicle damage" stipulated in Item 8, Paragraph 1, Article 4, of the Ordinance on Report on Railway Accidents, etc., the Ministerial Ordinance No.8, Ministry of Transportation, 1987, and found by other than the periodic inspections, and recognized as should be cleared up the causes objectively from a technical point of view, the Japan Transport Safety Board determined the serious incident as the subject of the investigation which was the "Incidents that are particularly rare and exceptional" subscribed in Item 6, Article 2, of the Ordinance for Enforcement of the Act for Establishment of the Japan Transport Safety Board, the Ministerial Ordinance No.124, Ministry of Land, Infrastructure, Transport and Tourism, 2001.

On August 26, 2019, the Japan Transport Safety Board appointed the chief investigator and one railway accident investigator in charge of investigation of the serious incident.

The Kinki District Transport Bureau dispatched its staffs to the incident site, etc., to support

investigation of the serious incident.

1.2.2. Implemented Period of the Investigation

Investigating item	Implemented date
Investigation of Bogie etc.	August 27 and 28, September 2, 26 and 27, October 15 and 16, November 5 to 7, December 2 and 3, 2019 January 22, 2020
Hearing statements on the process of the operation	August 27, 2019

1.2.3. Comments from Parties Relevant to the Probable Causes

Comments were invited from Parties Relevant to the probable causes.

2. FACTUAL INFORMATION

2.1. Process of the Train Operation

According to the statements of the driver and the conductor of the train, which was operated as the outbound 241 train "Rapi:t β41", started from Namba station of Nankai Main Line bound for Kansai Airport station, and after arrived at Kansai Airport station turned back as the inbound 250 train bound for Namba station, etc., of Nankai Electric Railway Co., Ltd., *hereinafter referred to as "the driver", "the conductor", "the train", "the company", respectively*, and the dispatcher of the transport dispatcher's office, *hereinafter referred to as "the dispatcher",* who received the communication from the conductor, and the vehicle inspection staffs A and B of the Hagurazaki Vehicle Inspection Branch who got on the train and inspected vehicles, and the vehicle inspection staff C in the Suminoe Vehicle Inspection Division who found the crack, the summary of the process to the serious incident were as follows.

(1) Driver

The day before the occurrence of the serious incident, the train, *i.e.*, the outbound 241 train, departed from Namba station on schedule at 18:00, and arrived at Kansai Airport station on schedule at 18:39. The driver did not feel any abnormality while operating the train. After that, the train turned back from Kansai Airport station, and departed from Kansai Airport station as the inbound 250 train on schedule at 19:05.

After departed from Sakai station, the driver heard the dispatcher and the conductor talking on the train radio. The content was that the dispatcher confirmed the conductor about abnormal sound from the coupling part between the 2nd and the 3rd vehicles. However, there was no direct contact from the conductor or the dispatcher, then the driver continued train operation as it was because there was no abnormality in the operation and arrived at Namba station on schedule at 19:46.

(2) Conductor

The conductor boarded on the train from Namba station and departed from Namba station on schedule. When patrolling the cabins in the section between Sakai station and Kishiwada station, the conductor noticed that a metallic sound as "squeaking" was heard from around the bottom of the gangway footplate at the coupling part between the 2nd and the 3rd vehicles responded to the shaking of the vehicles. It was not the first time that the conductor heard such sound, but she felt it was higher than as usual. As scheduled to be on duty for the inbound 250 train after turned back at Kansai Airport station, she thought about responding it if she heard the sound in the train as well.

The inbound 250 train departed from Kansai Airport station on schedule. The conductor noticed that the similar sound was heard from the coupling part between the 2nd and the 3rd vehicles when patrolling the cabins in the sections between Kansai Airport station and Rinku Town station, between Izumisano station and Kishiwada station, and between Kishiwada station and Sakai station. After departed from Sakai station, when she confirmed the sound at the coupling part between the 2nd and the 3rd vehicles, it was still making the sound. Therefore, she returned to the driver's cab in the 1st vehicle and reported to the dispatcher using the train radio that "There is one defect in the train. The sounds, as metals are rubbing with each other, was heard from the bottom of the gangway footplate at the coupling part between the 2nd and the 3rd vehicles while running. Please contact with the relevant sections."

In addition, the conductor informed to the conductor who was replaced at Namba station that there was a sound as metals are rubbing with each other while running from under the gangway footplate of the coupling part of the 2nd and the 3rd vehicles, and already reported them to the dispatcher.

(3) Dispatcher

The dispatcher received a report from the conductor that there was the sound as metals are rubbing with each other while running from under the gangway footplate of the coupling part between the 2nd and the 3rd vehicles, so this information was shared with the vehicle inspection dispatcher, *hereinafter referred to as "the vehicle inspection dispatcher"*, of the Vehicle Inspection Command Division. When the inbound 250 train almost arrived at Namba station, the vehicle inspection dispatcher asked to confirm the conductor whether the train was running on a straight track or a curved track when the abnormal sound was heard. Then I confirmed that with the operation supervisor, refer to 2.8.1, of the conductor, and told that there was no sound in a straight track but in a curved track, then I reported it to the vehicle inspection dispatcher. After that, the vehicle inspection dispatcher contacted me saying that "We are arranging vehicle inspection staffs for the outbound 249 train, so please take a look at the situation".

When the outbound 249 train almost arrived at Kansai Airport station, the vehicle inspection dispatcher reported me that the confirmation was implemented by boarding on the train but there was no abnormality, so I communicated with the operation supervisor of the conductor and reported that there was no abnormality.

(4) Vehicle inspection staff A

The vehicle inspection staff A was instructed from the chief of the Hagurazaki Vehicle Inspection Branch to get on the train and check the situation, because there was a strange sound from the coupling part between the 2nd and the 3rd vehicles of the train. It was said that there was a metallic sound while running, but it was not known whether the metallic sound occurred in a curved track, where it came from in the coupling part, or who made the declaration. The train inspection staff A got on the train near the coupling part between the 2nd and the 3rd vehicles from Izumisano station, but there was no noise at all. After arrived at Kansai Airport station, he reported to the chief of the Hagurazaki Vehicle Inspection Branch by his mobile phone that any strange sound to be worried could not be confirmed.

(5) Vehicle inspection staff B

The vehicle inspection staff B was instructed from the chief of the Hagurazaki Vehicle Inspection Branch that "there was a noise coming from the coupling part between the 2nd and the 3rd vehicles of the train, so please get on the train and check the situation". When he got on the train, the sound was heard from the gangway footplate and side panel*1, but he thought they were all normal sounds.

(6) Vehicle inspection staff C

I was instructed from the vehicle inspection dispatcher that "since there is a metallic sound while running from the coupling part between the 2nd and the 3rd vehicles of the train, the vehicle inspection staffs of the Hagurazaki Vehicle Inspection Branch will board on the train from Izumisano station. Please check again when the train entered the depot". After that he contacted the chief of the Hagurazaki Vehicle Inspection Branch and asked about the result of the boarding inspection, answer was that "There was no sound in the side panel".

After that, the train arrived at the depot and I started the inspection and investigated the side panel, but since there was no abnormality, then, I decided to inspect the underfloor of the vehicles. As investigated the buffering and draw gear of the coupler, but no abnormality was found, next I checked the surroundings of the motor, and found the crack in backside of the traction motor support of the 1st axle of the 2nd bogie in the 2nd vehicle, *hereinafter referred to as "the crack", "the bogie", "the vehicle", respectively.*

[Refer to Attached Figures 1 and 2]

*1 *"Side panel" is one of the parts of inner bellows with panel. It is composed of a total of three side panels, i.e., one in the center side and two in vehicle body side. [Refer to Attached Figure 5]*

2.2. Information on the Railway Facilities, etc.

The outline of the routes of Nankai Main Line and Airport Line are as follows.

(1) Nankai Main Line

Nankai Main Line of the company starts from Namba station to Wakayamashi station, railway business mile of 64.2 km, the double track with the gauge of 1,067 mm. The power is the electricity of DC 1,500 V.

(2) Airport Line

Airport Line of the company starts from Izumisano station to Kansai Airport station, railway business mile of 8.8 km, the double track with the gauge of 1,067 mm. The power is the

electricity of DC 1,500 V. The section between Rinku Town station and Kansai Airport station, is operated by the company as the Class 2 railway operator[*2] and New Kansai International Airport, Ltd., as the Class 3 railway operator[*3]. Kansai Airport Line of West Japan Railway Company shares the same tracks, both up and down tracks, except for the premises of the both stations.

As a side note, the "Rapi:t" is the limited express train operated between Namba station and Kansai Airport station, 42.8 km, double track section. The faster access type trains are called as the "Rapi:t α", and the other trains are called as the "Rapi:t β".

[Refer to Attached Figure 1]

*2 *"Class 2 railway operator" is the business operator that transports passengers or freight by railways using the railway track other than the railway tracks constructed for oneself.*

*3 *"Class 3 railway operator" is the company that constructed the railway tracks and allows to whom manages the Class 2 railway operators to use them exclusively.*

2.3. Information on the Vehicles

2.3.1. Information on the Train

The outline of the train is shown in Fig. 1. The major specifications of the vehicle are as follows.

Vehicle category	DC electric railcar, powered by DC 1,500 V
Vehicle type	The 50000 Series
Number of vehicles in the trainset	6 vehicles trainset
Capacity of the trainset	252 persons
Maximum speed	110 km/h in Nankai Main Line 120 km/h in Airport line
Vehicle number of the vehicle	50204, the 2nd vehicle of the 04 trainset
Tare of the vehicle	38.2 *t*[*4]
Completion of the vehicle	April 1994
Type of the bogie	SS137
Suspension system of the vehicle body	Bolsterless type
Suspension system of the wheel axle	SU Minden type[*5]
Driving system	Flexible plate joint type parallel cardan
Traction motor	Squirrel cage three phase induction motor
Manufactured date of the bogie	April 1994

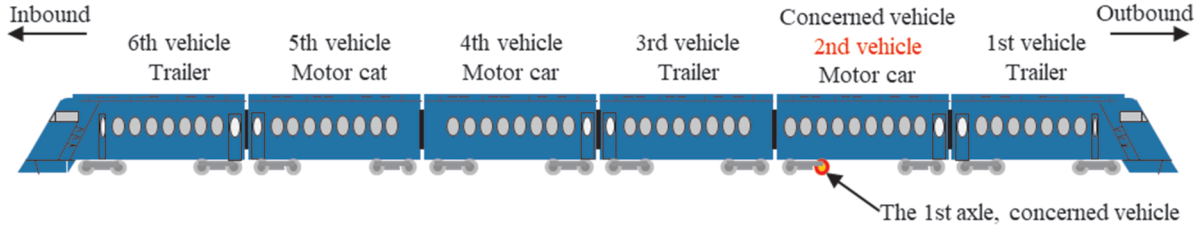


Figure 1. Outline of the train

The accumulated running distance of the vehicle from the start of use to the occurrence of the serious incident was about 4.156 million km. In addition, the accumulated running distance of the bogie is the same as that of the vehicle, because the bogie was removed and inspected at the time of the general inspection, etc., described in 2.5.4 "Status of inspection of traction motor support", and after finished the inspection attached to the same position again for use.

*4 *[Unit conversion] 1 t = 1,000 kg-weight, 1 kg-weight : 1 kg-force, 1 kg-force = 9.8 N*

*5 *"SU Minden type" is a method in which two leaf springs are pulled out from the center side of the bogie frame and the axle box is elastically connected to the bogie frame to hold the axle box. A method in which the rigidity in the horizontal direction is reduced using the rubber bush attached to the support part of the leaf spring.*

2.3.2. Outline of the Structures, etc., of the Bogie

The bogie is composed of two wheel axles in front and rear, a bogie frame above the wheel axles, driving equipment including the traction motor, and the braking device, etc. The bogie frame is composed of left and right side beams that support the distance between the front and rear wheel axles and support the weight of the vehicle, and the longitudinal and lateral load weights, and the cross beam that connect them. The traction motor support where the crack had generated is attached to the cross beam by welding.

The cross beam was manufactured by press working and bending a rolling steel material for welded structures with a thickness, nominal thickness, of 12 mm stipulated in the Japanese Industrial Standards, *hereinafter referred to as "the JIS standard",* so that the cross section becomes in "U" shape. After that, the two bent materials are butt welded and assembled so that the cross section becomes a "square" shape.

The traction motor support is the supporting base for mounting the traction motor, and its size is 400 mm in height, in vertical direction, 415 mm in width, in the direction of sleepers, and 190 mm in width, in the direction of rail. It is the structure assembled by welding the rolled steel for welding structure with a thickness of 12 mm in the JIS standards, the nominal thickness, and attached to the cross beam with fillet welding*6 with a groove.

The equipment for driving of the bogie composed of the gear device attached to the wheel axles, the traction motor attached to the traction motor support, and the coupling that transmit the torque of the traction motor to the gear units as to allow the relative displacements in the vertical, horizontal, and front-rear directions that occurs between them while running.

[Refer to Attached Figure 3]

*6 *"Fillet welding" is the welding having a triangular cross section between materials.*

2.3.3. Information on the Vehicle Maintenance, etc.

2.3.3.1. Implemented date, etc., of the inspection of the vehicle

As for the vehicle maintenance in the company, the inspections have been implemented based on the "Vehicle related Implementing Standards, maintenance of ordinary railway" and the related documents "Rules of Inspection Work", which are a part of the implementing standards reported by the company to the Director General of the Kinki District Transport Bureau based on

the "Ministerial Ordinance Providing for the Technological Standards for Railways", Ministerial Ordinance No.151 stipulated by the Ministry of Land, Infrastructure, Transport and Tourism, 2001, *hereinafter referred to as "the Technical Standards"*.

The implemented status of the general inspection[*7], the critical parts inspection[*8], the status and function inspection[*9] and the train inspection[*10] implemented just before the occurrence of the serious incident on the vehicle, are as shown in Table 1.

Table 1. Implemented status if the inspections

Type of inspection	Implemented date & running distance	Inspection implemented site
General inspection	April 15, 2013 / 1,114,635.4 km	Chiyoda Factory
Critical parts inspection	April 21, 2016 / 560,016.4 km	Chiyoda Factory
Status and function inspection	July 22, 2019 / 16,765.0 km	Suminoe Vehicle Inspection Division
Train inspection	August 15, 2019 / 3,860.2 km	Suminoe Vehicle Inspection Division

* "Running distance" in the table is the running distance of the vehicle after implemented each inspection till to the occurrence of the serious incident.

The inspecting contents of the critical parts inspection for the vehicle is targeted the newly built vehicles adopted the VVVF control to the control system after 1990 and the remodeled vehicles in which the control system was modified to the VVVF control after April 2005, and the inspection was implemented without dismantle the bogies from the vehicle body, and omitted measurement and management of static wheel load and flaw detection test, etc., for axles and bogie frames.

In any of the inspections shown in Table 1, there was no record indicating that there was an abnormality in the bogie frame.

Details of the periodic inspection of the bogie frame are described in 2.5.4.

*7 *"General inspection" is the inspection performed after disassembling each part of the entire vehicle. The inspection cycle is prescribed as to be a period not exceeding 8 years.*

*8 *"Critical parts inspection" is the inspection performed on the major parts of the traction motor, power transmission device, running device, braking device, and vehicle body, etc. The inspection cycle is prescribed as 4 years or a period not exceeding 600,000 km.*

*9 *"Status and function inspection" is the inspection performed in the on-condition status for the statue, action, and function of current collectors, running devices, electric devices, braking devices, vehicle bodies, etc. The inspection cycle is prescribed as the period not exceeding 3 months.*

*10 *"Train inspection" is the inspection performed from the outside regarding the replenishment and replacement of consumables and the inspection for the condition and operation of current collectors, running devices, electric devices, braking devices, vehicle bodies, etc. The inspection cycle prescribed as the period not exceeding 10 days.*

2.3.3.2. The Onboard Inspection of the Train in the Section between Izumisano Station and Kansai Airport Station

According to the statements, the onboard inspection of the train was conducted by the vehicle inspection staffs in the section between Izumisano station and Kansai Airport station as follows, but no abnormalities were confirmed.

(1) The conductor of the inbound 250 train informed by the train radio to the dispatcher that "There is one defect in the train. The sounds, as metals are rubbing with each other, was heard from the bottom of the gangway footplate in the coupling part between the 2nd and the 3rd vehicles while running. Please contact with the relevant sections."

(2) The vehicle inspection dispatcher instructed the chief of the Hagurazaki Vehicle Inspection Branch to board on the outbound 249 train from Izumisano station and to check the sound as metals are rubbing with each other. The chief of the Hagurazaki Vehicle Inspection Branch, as received the instruction, instructed the vehicle inspection staffs A and B to get on the train from Izumisano station.

(3) The vehicle inspection staffs A and B of the Hagurazaki Vehicle Inspection Branch boarded on the outbound 249 train from Izumisano station to Kansai Airport station while checking the abnormal sound.

(4) The vehicle inspection staffs A and B of the Hagurazaki Vehicle Inspection Branch could not confirm the abnormal sound as the result of the boarding inspection, so they called the chief of the Hagurazaki Vehicle Inspection Branch and reported as "We could not confirm any noise to be worried".

[Refer o Attached Figure 2]

2.4. Information on Damages and Traces of Railway Facilities and Vehicle

2.4.1. Damaged Status, etc., of the Bogie

When the vehicle inspection staff C conducted a vehicle inspection at the Suminoe Vehicle Inspection Division of the company, where the serious incident occurred, the crack was found in the upper part of the reinforcing ribs, *hereinafter referred to as "the reinforcing rib"*, attached to the welded part between the cross beam and the traction motor support of the bogie.

There was no abnormality in the mounted status of the traction motor, and there was no abnormality in the gear unit and the coupling either. *[Refer to Attached Figure 3]*

2.4.2. Damaged Status, etc., of Traction Motor Support

The crack was cut from the bogie of the vehicle and was investigated in detail, as the results, the damaged status of the crack was as follows.

(1) The crack was generated at the welded part between the backside of the traction motor support in the cross beam and the reinforcing rib, and was about 140 mm in length and about 1 mm in width.

(2) When observed the broken surface of the crack, multiple ratchet marks[*11] were found as extended outward.

(3) The striation*12 was found as extended outward at the end of the welded part.

(4) The EDX analysis*13 was carried out and the substance adhered to the broken surface of the crack was analyzed, as the results, a small amount of titanium, Ti, was detected in a part of the broken surface. Here, the titanium is used as a raw material for welding materials and paints applied to bogie frames.

*11 *"Ratchet mark" is one of the features that occur in the fracture surface of fatigue fracture, and the stepped trace that occurs near the starting point. It is also called a step pattern.*

*12 *"Striation" is the characteristic striped pattern that is seen on the fracture surface when fatigue cracks propagated, and is usually small as to be seen only with an electron microscope.*

*13 *"EDX analysis" is the energy dispersive X-ray spectrometry, which is used for detecting foreign substances on the surface of a material and identifying its constituent elements, and used in this investigation for the purpose of detecting paint components, etc.*

2.4.3. Damaged Status, etc., of Other Traction Motor Support found in the Urgent Inspection

The company inspected the traction motor supports, for 36 bogies and 72 positions, in all bogies of the 50000 Series vehicles in all 6 trainsets, responded to the occurrence of the serious incident, and found four cracks in the same part. These cracks were cut and the damaged status was investigated in detail. The status of the found cracks was as shown in Table 2.

Table 2. Status of the found cracks

Vehicle & Trainset	Wheel axle & bogie	Crack length	Found inspection method
The 2nd vehicle, the 5th trainset	The 1st axle of the 2nd bogie	About 70 mm	Visual inspection
The 4th vehicle, the 4th trainset	The 2nd axle of the 2nd bogie	About 60 mm	Magnetic particle inspection*14
The 5th vehicle, the 6th trainset	The 1st axle of the 2nd bogie	About 60 mm	Magnetic particle inspection
The 5th vehicle, the 6th trainset	The 2nd axle of the 1st bogie	About 20 mm	Magnetic particle inspection

2.4.3.1. Status of damaged surface of the crack in the 2nd vehicle of the 5th trainset

The crack in the 2nd vehicle of the 5th trainset was cut and investigated in detail, the damaged status of the crack was as follows.

(1) The broken surface of the crack was observed and the beach marks*15 were found in both the damaged surface of the reinforcing rib side and the damaged surface on the cross beam side. In addition, it was confirmed that plural ratchet marks extended outward.

(2) The welding defects*16 such as the blowhole*17 and the incomplete fusion*18, etc., were found at the welded parts between the cross beam and the reinforcing rib.

(3) It was confirmed that there was a gap between the cross beam and the reinforcing rib.

(4) The EDX analysis was carried out to analyze the substances adhered to the broken surface of the crack, but components related to the paint such as titanium, Ti, could not be confirmed definitely.

[Refer to Attached Figure 4]

*14 *"Magnetic particle inspection" refers to a non-destructive test that visualizes and detects flaws on and near the surface by a leaking magnetic field. It uses a suitable test medium containing magnetic powder.*

*15 *"Beach mark" is a characteristic striped pattern that is seen on the fracture surface when fatigue cracks propagate, and is usually large enough to be visible.*

*16 *"Welding defects" are those that deviate from the ideal welding and are unacceptable.*

*17 *"Blowhole" is the spherical cavity formed in the weld metal.*

*18 *"Incomplete fusion" is that the boundary surface of welded part is not sufficiently fused with each other.*

2.4.3.2. Status of broken surface of the crack in the 4th vehicle of the 4th trainset

The crack in the 4th vehicle of the 4th trainset was cut and investigated in detail, the damaged status of the crack was as follows.

(1) When observed the broken surface of the crack, it was confirmed that plural ratchet marks extended outward. In addition, a welding defect was confirmed in the central part.

(2) The striation extending outward was confirmed at the end part of the welded part.

2.4.3.3. Status on broken surface of the crack in the 5th vehicle of the 6th trainset

The two cracks in the 5th vehicle of the 6th trainset were cut and investigated in detail, the damaged status of the cracks were as follows.

(1) When observed the broken surfaces of the cracks, it was confirmed that plural ratchet marks extended outward.

(2) Striation extending outward was confirmed at the end part of the welded part.

(3) When EDX analysis was conducted and analyzed the substances adhered to the fractured surface, a small amount of titanium, Ti, was detected on a part of the broken surface.

2.5. Information on Traction Motor Support

2.5.1. Status of Strength Design and Verification of Traction Motor Support

As a result of the investigation by the company and the company who manufactured the bogie, *hereinafter referred to as "the bogie maker"*, the actual status of the strength design and the verification of the bogie frame for the 50000 Series vehicles were as follows.

(1) The evaluation of strength in the strength design of the bogie was carried out based on the method stipulated in the JIS standard "JIS E 4207, 1984, General Rules in Designing Railway Vehicle, Bogie, Bogie Frame", *hereinafter referred to as "the JIS E 4207, 1984"*. Regarding the stress generated in each part of the bogie frame used in the evaluation; the measured value of the stress obtained by carrying out the static load test specified in "JIS E 4208, 1984, Test method for railway vehicle, bogie, load", was used.

(2) After that, bogie was assembled into the 50,000 Series vehicle, and the running test was conducted as the on-track test in Nankai Main Line and Airport Line, and the obtained maximum and the minimum values of the actual working stress, *i.e.*, the tensile stress and the compressive stress, were evaluated based on the methods determined in the JIS E 4207, 1984.

2.5.2. Added Status of Reinforcement, etc., to the Traction Motor Support

Table 3 shows the results of an investigation on the added status of reinforcement, etc. to the traction motor support.

Table 3. Added status of reinforcement, etc. to the traction motor support

Year	Reinforced part
1998	Let well known widely on the measures against cracks that occurred in the other operators. - Add a block to the side surface of the traction motor support. - Overlay welding and grinder finishing of the welded part between upper surface of traction motor support and the cross beam. - Grinder finishing of the welded part between backside of the traction motor support and the cross beam.
2005	Implemented measures to improve strength of bogie frame as a measure against cracks that occurred in the traction link support. - Added the reinforcing rib to the upper surface of the traction motor support. - Added the reinforcing rib to the backside of traction motor support.
2017 2019	Implemented as a measure against the crack generated in the vertical plate of the traction motor support. - Grinder finishing of the welded part of the vertical plate of the traction motor support.

2.5.3. Added Status of the Reinforcing Rib

The company conducted a stress measurement during the running test when a crack had generated in the traction link support described in 2.5.2. In the backside of the traction motor

support to which the reinforcing rib was attached later, it was confirmed that the measured stresses exceeded the limit of stress at some parts other than the traction link support, although the margin of generated stress against the allowable stress was small, the measured stress was within the permissible range. Therefore, as a measure to improve the strength of the entire bogie frame, it was decided to add two reinforcing ribs including the reinforcing rib listed in the line of 2005 in Table 3. Here, the strength at the time of the running test was evaluated by the method specified in JIS standard "JIS E 4207, 2004, General Rules in Designing Railway Vehicle, Bogie, Bogie Frame".

2.5.3.1. Circumstances of the addition of the reinforcing rib

Regarding the works to add the reinforcing rib, the company and the bogie maker examined the constructing method so as not to hinder the operation of the Limited Express "Rapi:t", and decided that the bogie maker took over the bogie frame at the time of the general inspection, and carry out the construction to add the reinforcing rib in the plant of the bogie maker. The constructing status is as shown in Table 4.

Table 4. Circumstances to the addition of the reinforcing rib

Time	Contents
June 2003	The crack generated in the traction link support
October 2003	The company and the bogie maker conducted a running test to investigate the cause of the crack in the traction link support, and confirmed that the stress in the place, where the crack had generated, had exceeded the limit.
February 2005	The company and the bogie maker had a meeting about the reinforcement shape to be implemented as a measure to improve the strength of the entire bogie frame.
March to July 2005	The bogie maker drew up a reinforcing plan of traction motor support, *i.e.*, reinforcement drawing, work plan, board cutting plan.
March 2005	The bogie maker drew up the drawing of traction motor support reinforcement.
June 2005	The bogie maker put out the drawing of traction motor support.
June 2005	The bogie maker drew up a reinforcement work plan.
July 2005	The bogie maker drew up a board cutting plan.
July 2005 to August 2007	Implemented work to add the reinforcing rib for all 6 trainsets of the 50000 Series vehicles.

2.5.3.2. Design of the installation of the reinforcing rib

According to the bogie maker, when designing the installation of the reinforcing rib, it was decided to attach the reinforcing ribs at the same time as starting the general inspection, but the construction period was short and there was no time to correct the thermal distortion due to welding, therefore, it was necessary to suppress the distortion of the traction motor support. In

order to suppress the distortion, it is necessary to suppress heat input as much as possible, therefore, the double groove was adopted instead of the single groove, and double fillet welding was adopted, in order to reduce the size of the reinforcing rib and the amount of welding.

Here, it is probable that the residual stress due to welding is suppressed, because the material of the traction motor support and the reinforcing rib of the vehicle are the soft steel SM400B.

According to the bogie maker, the result of comparison on the welding amount in design between double groove and single groove, is shown in Figure 2.

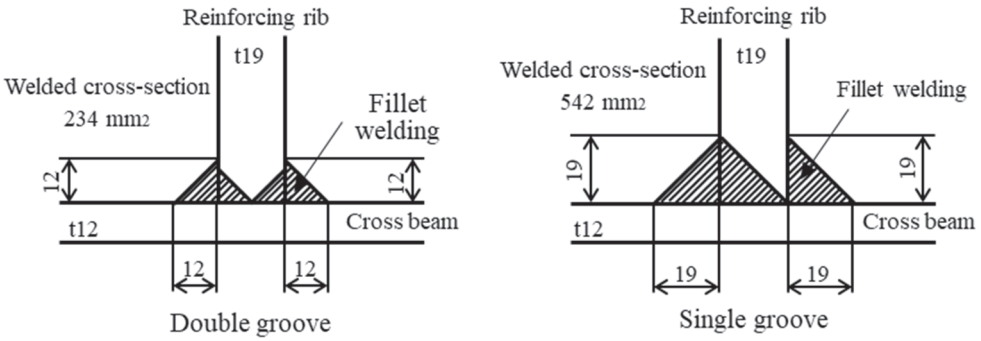


Figure 2. Comparison of welding amount between single groove and double groove

The bogie maker has a "design room for creating drawings" and a "bogie technology management room for creating plans of works and board cutting, *i.e.*, cutting method of the parts material". The drawings for the reinforcing rib installation were created in the design room and the work plan and the board cutting plan were created based on the drawings in the bogie technology management room. The work plan was submitted to the welding work site where welding work is performed, and the board cutting plan was submitted to the cutting work site where parts material is cut.

In addition, regarding the flow of reinforcement rib installation work to be examined in the bogie technology management room, usually, the steel plates are cut and the groove processing and confirmation of parts material are performed in the cutting work site. After that, temporary attachment and welding are performed in the welding work site. However, regarding the flow of the reinforcing rib installation work, the parts material are small in size and the groove processing cannot be performed by the equipment in the cutting work site. Therefore, after cutting the steel plate and checking the parts material only were implemented at the cutting workplace, the temporarily attachment, the groove processing and welding are performed at the welding workplace. Here, it is decided to perform the groove processing by the air gouging[*19] in the welding work site. As it is considered to outsource the groove processing of the reinforcing rib, but since the period from the decision of the reinforcement work method to the start of the first construction was short and as it was judged that the groove processing was able to be performed by air gouging, it was decided that the reinforcement rib installation work was not outsourced.

The drawings prepared by the design office and sent to the welding work site contained instructions regarding the groove processing, but there was no explanation regarding performing

groove processing at the welding work site and performing by the air gouging. In addition, since the board cutting plan for installing the reinforcing rib no longer requires the groove processing in the cutting work site, it was described as "the groove processing, double groove, by the AG after installed". On the other hand, the work plan only stated that "Assemble the reinforcing rib according to the drawing".

According to the bogie maker, this was the first time that the groove processing was performed in the welding work site, and for this reason, the work plan did not include instructions for the groove processing. In addition, even after that, the groove processing was not performed in the welding work site.

The flow of usual reinforcement work and the flow of the reinforcing rib installation work are shown in Figure 3.

*19 *"Air gouging" is a method to generate an arc between a carbon electrode and a metal to melt the metal, and at the same time, blown off the molten metal by jetting a high-speed jet parallel to the outside of the electrode. It is abbreviated as "AG".*

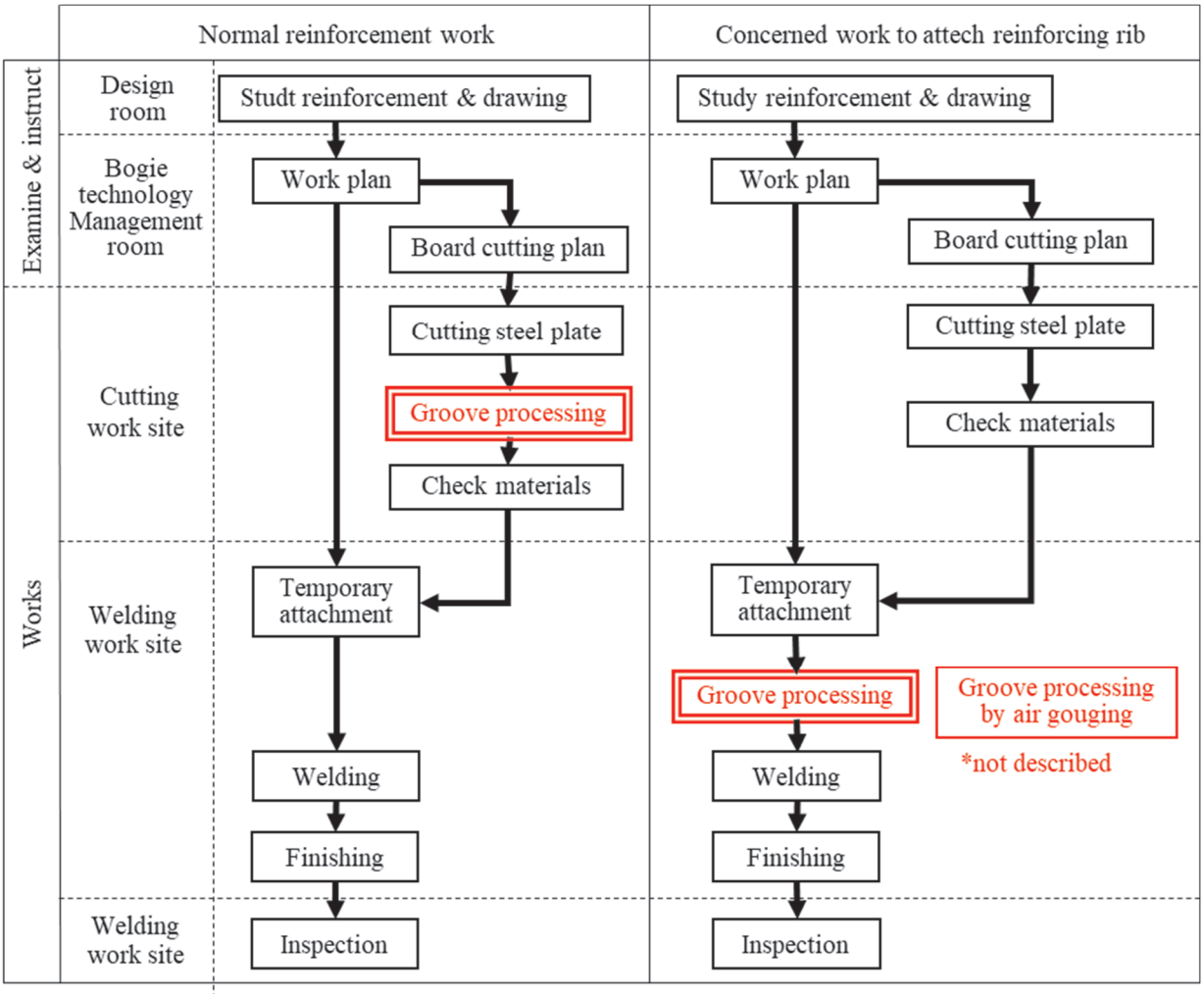


Figure 3. Comparison of the reinforcement work flow created by the bogie maker

2.5.3.3. Reinforcing rib installation work

According to the bogie maker, the bogie technical management room handed over the work plan and drawings to the work manager at the welding work site during the installation work of the reinforcing rib for the first trainset and explained the work contents. Although it was the first

time for workers to perform the groove processing by the air gouging, the work plan submitted to the welding workplace did not mention the groove processing. Therefore, there was a possibility that the bogie technical management room did not give a concrete explanation to the work manager about the groove processing.

There was a possibility that the workers who received the explanation on the work contents from the work manager welded without groove processing after temporary installed as in the case of usual reinforcement work during the reinforcing rib installation work. In addition, there was a possibility that the bogie with cracks in Table 2 was also welded without groove processing during the reinforcing rib installation work.

The welded part of the reinforcing rib welded without the groove processing is as shown in Figure 4.

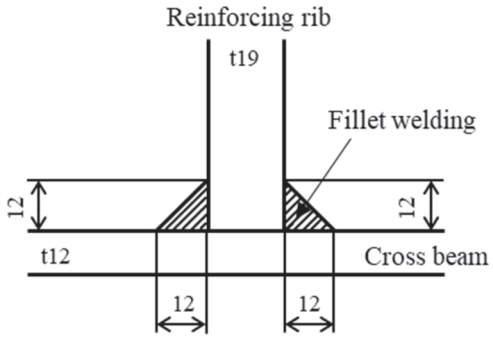


Figure 4. Welded part of reinforcing rib welded without groove processing

In addition, an ultrasonic flaw detection inspection is conducted to detect welding defects in the reinforcing rib in the inspection after welded, but it was prescribed to be performed perpendicular to a weld bead*20 in the work plan. It was not possible to confirm whether the groove process was performed by this method.

*20 *"Weld bead" is a raised portion formed on a joint surface by welding.*

2.5.4. Status of the Inspection of Traction Motor Support

Bogies of a railway vehicle are a part of the important running gear to secure the running safety and the stability of the vehicles. Therefore, the technical standards stipulated the followings.

[Running gear, etc.]

Article 67. The Running device shall comply with the following standards.

(i) to *(iv)* [Omitted]

(v) [Omitted], *the Running gear, etc. shall be rigid and have sufficient strength, and shall be able to secure safe and stable driving of the vehicles.*

The periodic inspection of vehicles is stipulated as follows.

[Periodic inspection of facilities and vehicles]

Article 90. Periodic inspections of facilities and vehicles shall be carried out by defining the inspection cycle, target parts and methods according to the type, structure and other conditions of use.

2. When the Minister of Land, Infrastructure, Transport and Tourism has specified in the notification, the matters concerning the periodic inspection set forth in the preceding paragraph shall be carried out in accordance with this.

Also, in the Article 5 "Periodic inspection of vehicles" in the "Notification of the periodic inspection of facilities and vehicles", Ministry of Land, Infrastructure, Transport and Tourism Notification No.1786, December 25, 2001, the period of the critical parts inspection and the general inspections, etc., have been stipulated.

In the company, the category, inspection items and methods of the inspection are stipulated in the "Vehicle related Implementing Standards". In addition, regarding the inspection of the bogie frame, the "Vehicle related Implementing Standards" stipulates that visual inspection and flaw detection test shall be performed according to the "Bogie Frame Inspection Manual".

As described in 2.5.4, the periodic inspections of the vehicle were conducted based on the "Vehicle related Implementing Standards" and the "Bogie Frame Inspection Manual".

According to the company, regarding the flaw detection parts of the bogie frame, the flaw detection parts were specified considering the occurred status of cracks in the other companies, in addition to the parts where relatively high stress is thought to occur.

As a countermeasure for the crack in vertical plate of the traction motor support, described in 2.6.1, the vertical plate of the traction motor support was specified as a priority inspection part from the general inspection on February 2018, to implement the flaw inspection. However, the reinforcement parts where the measures to improve the strength of the entire bogie frame described in 2.5.3 were not designated as a priority inspection part, and the flaw detection test had not been carried out.

2.6. Information on Status of the Past Crack Generation in the 50000 Series Vehicles

For the 50000 Series vehicles, as described in 2.5.2, cracks were generated in the bogies in 2005, 2017 and 2019. Among them, about the cracks that occurred in 2017 and 2019 appeared on the traction motor support as same as the crack, and their summaries are as follows.

(1) Date and time of occurrence : About 16:00, Monday, November 6, 2017

Related vehicle : 5th vehicle of the 4th trainset

Summary : While entering the factory for renewal works, a crack with a length of about 175 mm was found in the vertical plate of the traction motor support of the 1st axle of the 1st bogie of the 5th vehicle. As a result of the urgent inspection for the same part in the 4th trainset, about 38 mm crack in the same part of the 2nd axle of the 1st bogie of the 5th vehicle, about 40 mm crack in the same part in the 1st axle of the 2nd bogie of the 2nd vehicle, about 65 mm crack in the same part in the 2nd axle of the 1st bogie of the 2nd vehicle were found.

Based on the results of stress measurement by a running test and the FEM analysis, relatively high stress was generated in the vicinity of the cracks generated in the vertical plate of the traction motor support.

(2) Date and time of occurrence : About 15:40, Monday, April 8, 2019

Related vehicle : 4th vehicle of the 1st trainset

Summary : A crack of about 140 mm was found in the traction motor support of the 2nd axle of the 2nd bogie of the 4th vehicle in the train inspection. The place of the crack generation was the same as the place where the crack occurred on the 5th vehicle of the 4th trainset in 2017.

In the urgent inspection conducted when the crack was found in November 2017, a simultaneous investigation was carried out by the ultrasonic flaw detection, therefore, it seems that the crack found in the urgent inspection was progressed after the simultaneous investigation.

2.7. Information on the Generation of Abnormal Sound

When a survey was conducted by boarding a commercial train in order to identify the location of the abnormal sound, it was found that a metallic noise was generated at the coupling part of the vehicles when vehicles moved up and down while running in the curved section.

The place where the abnormal sound was generated was the center side of the side panel mounting part of the panel bellows on the gangway footplate of the coupling part between the 2nd and the 3rd vehicles and was generated when the guide pin rubbed against the guide.

[Refer to Attached Figure 5]

2.8. Information on the Train Crews, etc.

The driver was the 47 years old male, having the driver's license of the Class A electric railcar issued on March 26, 2014, and experienced for about 5 years and 5 months.

The conductor was the 26 years old female, experienced for about 3 years and 8 months.

The dispatcher was the 43 years old male, experienced for about 1 year and 1 month.

The vehicle inspection staff A was the 43 years old male, experienced for about 24 years and 5 months.

The vehicle inspection staff B was the 33 years old male, experienced for about 10 years and 11 months.

The vehicle inspection staff C was the 46 years old male, experienced for about 27 years and 5 months.

2.8.1. Organization of the Train Crews

The crews in the train were one driver and one conductor. These crews were scheduled to be on duty for the outbound 241 train, after that, continues to be on duty for the inbound 250 train which had turned back at Kansai Airport station, and will be replaced at the final destination Namba station.

The command system of the conductor is shown in Figure 5.

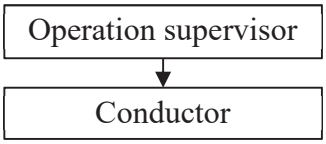


Figure 5. Command system of the conductor

2.8.2. Organization of the Dispatchers

The command system of the company consists of the transport dispatcher, the vehicle inspection command division, and the electric power command division, and the chief transport dispatcher supervises the command work on the day. Figure 6 shows the command system of the transport command and the vehicle inspection command division stipulated in the "Transport Command Operation Handling Standards" and the "Railway Staff Job Management and Office Regulations" of the company.

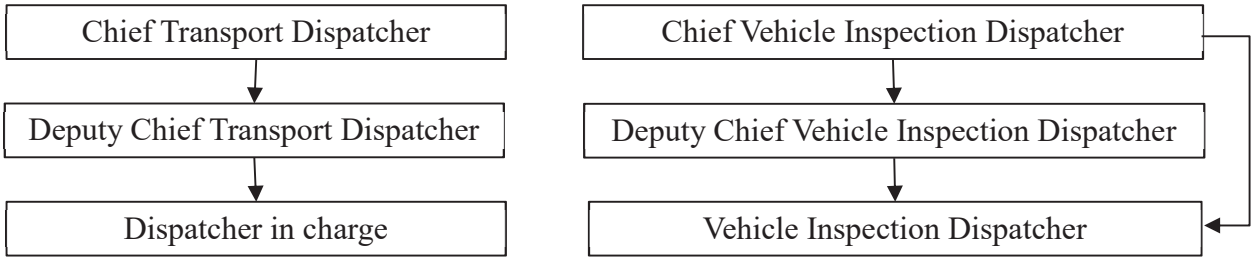


Figure 6. Command system of transport command and vehicle inspection command division

2.9. Information on the Handling Operation

2.9.1. Regulations on Handling by the Train Crews in an Abnormal Situation

The "Train Division Crew Work Internal Rules", "Train Division Handling Operation Standards" and "Conductor Work Procedure" of the company stipulate the basic works and operations of the crews in carrying out their duties, and the handling in normal times and in abnormal situations to provide safe, accurate and comfortable transportation to railway users, based on the "Work Rules", "Railway Line Operation Handling Rules, etc. of the company.

The basic measures to be taken in the event of an abnormality are stipulated in the "Train Division Operation Handling Standards" as follows.

"Train Division Operation Handling Standards", excerpt

Chapter 2. Handling of trains

Section 8. Handling in case of abnormality

[Handling when an abnormality is found]

Article 41. When the driver and the conductor noticed that the train operation is hindered or might be hindered, appropriate measures must be taken such as promptly notifying the relevant stationmasters and commanders by the train radio or other methods. In this case, if there is an urgent situation, implement the train protection, including the issue of the train protection radio, and stop the trains traveling on the adjacent tracks.

[When a vehicle failure occurs]

Article 94. When an accident or a vehicle failure occurs on the train in charge, the driver and conductor must promptly notify the commander and inspect the location of the failure. If temporary measures cannot be taken, communicate to the relevant section by the train radio, the track side telephone, etc., and receive the instructions.

If there is a risk that the following train will be significantly hindered because temporary measures cannot be easily taken, appropriate measures such as pushing operation by locomotives should be taken.

2.9.2. Regulations on the Handling of Dispatchers in Abnormal Situation

The "Transportation Command Operation Handling Standards" and "Railway Staff Job System and Service Regulations" of the company stipulate the basic work and operations of dispatchers, etc., when carrying out their duties, and the handling in normal times and in abnormal situations, etc.

The basic measures to be taken in the event of an abnormality are stipulated in the "Transport Dispatcher Operation Handling Standards" and "Railway Staff Job System and Service Regulations" as follows.

"Transport Dispatcher Operation Handling Standards" [excerpt]

Chapter 2. Train Operation

[Handling in case of a vehicle failure]

Article 26. In the event of a vehicle failure, the following handling shall be carried out after comprehended the situation.

(1) If it is found that commercial operation is dangerous, implement the reschedule such as cancel the operation at the nearest station and stop handling passengers.

(2) In the event of a minor failure, designate a staff member to onboard warning, and consult with the vehicle inspection command division to arrange repairs and vehicle replacements, etc.

"Railway Staff Job System and Service Regulations", [excerpt]

Section 3. Vehicle Inspection Command Division

Article 428. The Chief of the Vehicle Inspection Command Division shall instruct the relevant person in charge to take urgent measures when the vehicle has an accident or a failure, and shall promptly report to the relevant sections.

3. ANALYSIS

3.1. Analysis on the Generation of the Crack

As described in 2.4.2 and 2.4.3, it is highly probable that the crack in backside of the traction motor support was generated from the welding defect in the upper part of the reinforcing rib in the welded part between the cross beam and the reinforcing rib, based on the followings.

(1) Welding defect such as poor fusion were confirmed in the welded part between the cross beam and the reinforcing rib.

(2) The beach marks found on the broken surface of the crack were found in both the broken surfaces in the reinforcing rib side and the cross beam side.

(3) Plural ratchet marks could be seen on the broken surface of the crack and extended outward.

In addition, it is highly probable that the generated crack extended to the outer surface due to fatigue and expanded further more to left and right.

3.2 Analysis on the Reinforcing Rib

3.2.1. Analysis on the Design of Installing the Reinforcing Rib

As described in 2.5.3.2, the board cutting plan created by the bogie technical management room of the bogie maker prescribed as "the groove processing, double groove, by the AG after installed", but the work plan only prescribed as "assemble the reinforcing ribs according to the drawing". Therefor the welding work site to which only the work plan was submitted did not know that groove processing would be performed by the air gouging.

Based on the above situation, it is probable that it was necessary to specifically describe the instructions regarding groove processing in the work plan, when groove processing could not be performed in the cutting work site.

As for the reason why the work plan did not mention that groove processing shall be performed by the air gouging, as described in 2.5.3.2, it was the first time to perform groove processing for the reinforcing rib installation work at the welding work site. Therefore, it is somewhat likely that the fact, that the instruction for the groove processing had never been described in the work plan, was related.

3.2.2. Analysis on the Installation Work of the Reinforcing Rib

As described in 2.5.3.3, in a welding work site that did not know that the groove processing was performed by air gouging, after temporarily attached the reinforcing rib, welding was performed without performing the groove processing, as a result, it is highly probable that the welding defect generated at the welded part between the cross beam and the reinforcing rib.

Regarding the fact that the workers in the welding work site did not know that the groove was processed by the air gouging, it is somewhat likely that there was no specific instruction to the welding work site, although it was the first time for the workers to perform groove processing by the air gouging. When there is a change in the work procedure, special attention is required, and it is necessary to give the work instructions clearly for the work, that is different from the usual work.

In addition, when such a change occurs, it is necessary to verify and confirm the work contents in advance in the bogie technical management room and the work site where the work is performed, not to omit the contents of the instruction.

Here, it could not be determined the reason, why there is a possibility that the specific instruction on the groove processing by air gouging was not instructed to the welding work site and the workers, because it could not be confirmed the specific work contents explained from the bogie technical management room to the work manager and from the work manager to the worker, respectively, and the situation at that time, as the work manager of the welding work site has already dead, and the memories of the related people at that time were ambiguous.

3.3. Analysis on the Periodic Inspections

As described in 2.5.4, the place where the crack was generated had not been designated as a priority inspection place, and the magnetic particle inspection had not been performed, so it is likely that the crack could not be found by the periodic inspection. It is necessary to designate the place where the generated stress margin is small compared to the allowable stress as the prior inspection place even after the reinforcement is implemented, and to conduct the magnetic particle test. For the 50000 series vehicles including the train, it is desirable to conduct magnetic particle test for the prior inspection place even in the critical parts inspection.

In addition, as described in 2.4.3 and 2.6, the cracks have been generated in the bogies of the 50000 series vehicles other than the vehicle. Therefore, it is considered as necessary to find out the causes in early stage and to continue to implement countermeasures as in the case that the cracks were found in the periodic inspection.

3.4. Analysis on the Relation between Crack and Abnormal Sound Confirmed by the Conductor

As described in 2.7, it is certain that the abnormal sound confirmed by the was generated in the the attached part of the side panel, center side, in the panel bellows on the gangway footplate part of the coupling part between the 2nd and the 3rd vehicles when the guide pin was rubbing against the guide. On the other hand, since the crack was generated on the backside of the traction motor support of the 1st axle on the 2nd bogie of the 2nd vehicle, it is hard to be considered that the metallic noise generated in the coupling part due to the influence of the crack because the crack was apart from the coupling. Therefore, it is highly probable that there was no relationship between the abnormal sound and the crack.

3.5. Analysis on Handling in the Event of an Abnormality

As described in 2.9.1, the conductor informed the dispatcher on the occurrence of abnormal sound by the train radio, based on the case of a vehicle failure stipulated in the "Train Division Operation Handling Standards" and requested to inform the relevant sections. In addition, as described in 2.9.2, it is probable that the dispatcher contacted the relevant sections and requested repairs based on the handling in the event of a vehicle failure stipulated in the "Transport Dispatcher Operation Handling Standards". Furthermore, it is probable that the vehicle inspection dispatcher

contacted the relevant sections and made arrangements for boarding inspection and requested the repair work based on the "Railway Staff Job System and Service Regulations".

Based on the above situation, it is probable that, although the occurrence of the abnormal sound is not a vehicle failure, it was treated in the same way as the occurrence of the vehicle failure, and boarding inspection was arranged and repairs were requested, and the prompt measures were taken.

4. PROBABLE CAUSES

It is highly probable that the serious incident was caused as the crack, which was generated in the welded part between the cross beam of the bogie frame of the vehicle and the reinforcing rib on the backside of the traction motor support, propagated due to fatigue and reached the outer surface.

It is highly probable that the crack was generated in the welded part between the cross beam and the reinforcing rib on the backside of the traction motor support, because the welding defect was created, as the groove processing had not been performed when the bogie manufacturer attached the reinforcing rib to the backside of the traction motor support, and the crack had generated from here as the start point.

It is probable that the groove processing was not implemented related with that the workers in the welding work site did not know that the groove processing shall be implemented, because there was no description about the grooving in the work plan issued by the bogie technical management office of the bogie manufacturer submitted to the welding work site, where the groove processing is performed, and there was no definite work instruction.

Furthermore, the place, where the crack was generated, was the place as the small margin of the stress against the allowable stress, but had not been designated by the company as the important place to be inspected after implemented the reinforcement, and the magnetic particle inspection had not been conducted, therefore, it is likely that the crack could not be found even if the crack had already generated at the time of the periodic inspection.

5. SAFETY ACTIONS

5.1. Measures for Prevention of the Recurrence Considered as Necessary

It is highly probable that this serious incident was caused by the cracks that generated in the welded part between the cross beam of the bogie frame of the vehicle and the reinforcing rib on the back of the traction motor support, which propagated due to fatigue and reached the outer surface.

It is highly probable that the crack was generated in the welded part between the cross beam of and the reinforcing rib on the backside of the traction motor support, because the welding defect was created, as the groove processing was not performed when the bogie maker attached the reinforcing rib to the backside of the traction motor support, and became to the start point of the crack generation.

In addition, it is likely that the crack could not be found in the periodic inspection, because the place where the crack had generated had not been designated as a prior inspection place by the company and the magnetic particle inspection had not been conducted.

In order to prevent the recurrence of such a situation, it is necessary to take the following measures.

(1) Work instructions accompanied the change of the method

If there is a change in the work method in the welding work site, such as a case that the groove cannot be processed in the cutting work site due to equipment restrictions, it is necessary to be more careful than usual. It is also necessary to give specific work instructions such as to describe instructions on the groove processing in the work plan in the welding work site. In addition, when such a change occurs, it is necessary to verify and confirm the work contents in advance between the bogie technical management room, the cutting workplace, and the welding work site, and take measures to prevent omissions in the instruction contents.

(2) Review of the prior inspection parts

It is necessary to designate the place where the value of the generated stress is small margin compared to the allowable stress, as a prior inspection place even after the reinforcement is carried out, and to conduct the magnetic particle test. In addition, for the 50000 series vehicles including the train, it is desirable to conduct magnetic particle inspection for the priority inspection place even in the critical parts inspection.

5.2. Measures Taken by the Company after the Serious Incident

(1) Urgent measures

(i) An urgent visual inspection for the bogie was conducted, from August 24 to August 26, 2019.

(ii) An urgent inspection for the bogie by magnetic particle test was conducted by August 31, 2019.

(2) Permanent measures

(i) Revision of bogie frame inspection manual

The place where the crack generated was added to the prior inspection place in the bogie frame inspection manual.

(ii) Review of the critical parts inspection

It is decided to confirm the prior inspection place by the magnetic particle test even in the critical parts inspection, which is conducted almost every four years.

5.3. Measures Taken by the Bogie Maker after the Serious Incident

(1) If the groove processing is difficult by the equipment in the cutting work site, describe the countermeasures in the work plan. In addition, when studying a work plan that includes a process different from the conventional one, verify the work content in the preliminary study meeting.

(2) After the completion of the initial works, hold the review meeting, and describe the

measures and countermeasures for the problems in the initial works in the work plan. In addition, it was decided to prohibit groove processing by air gouging.

5.4. Measures Taken by the Ministry of Land, Infrastructure, Transport and Tourism after the Serious Incident

The Ministry of Land, Infrastructure, Transport and Tourism has taken the following measures in light of the occurrence of the serious incident.

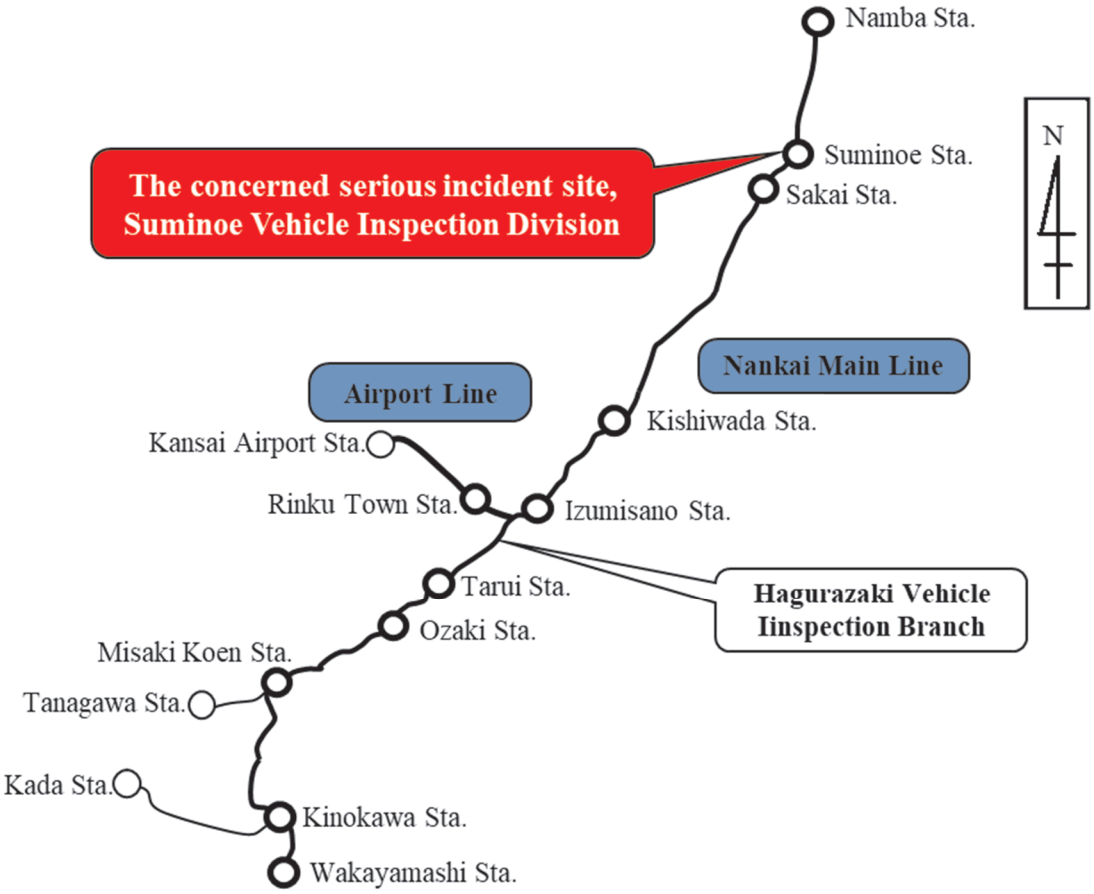
(1) On August 26, 2019, instructed "Nankai Electric Railway Co., Ltd., to "find out the causes and take measures to prevent recurrence", and on September 2, 2019, instructed the other railway and tramway operators to "share information and take cautions".

(2) On September 20, 2019, instructed the other railway and tramway operators, who own the bogies manufactured by the bogie maker, to perform urgent inspection visually or other method in the on-condition status for the welded part in the traction motor support.

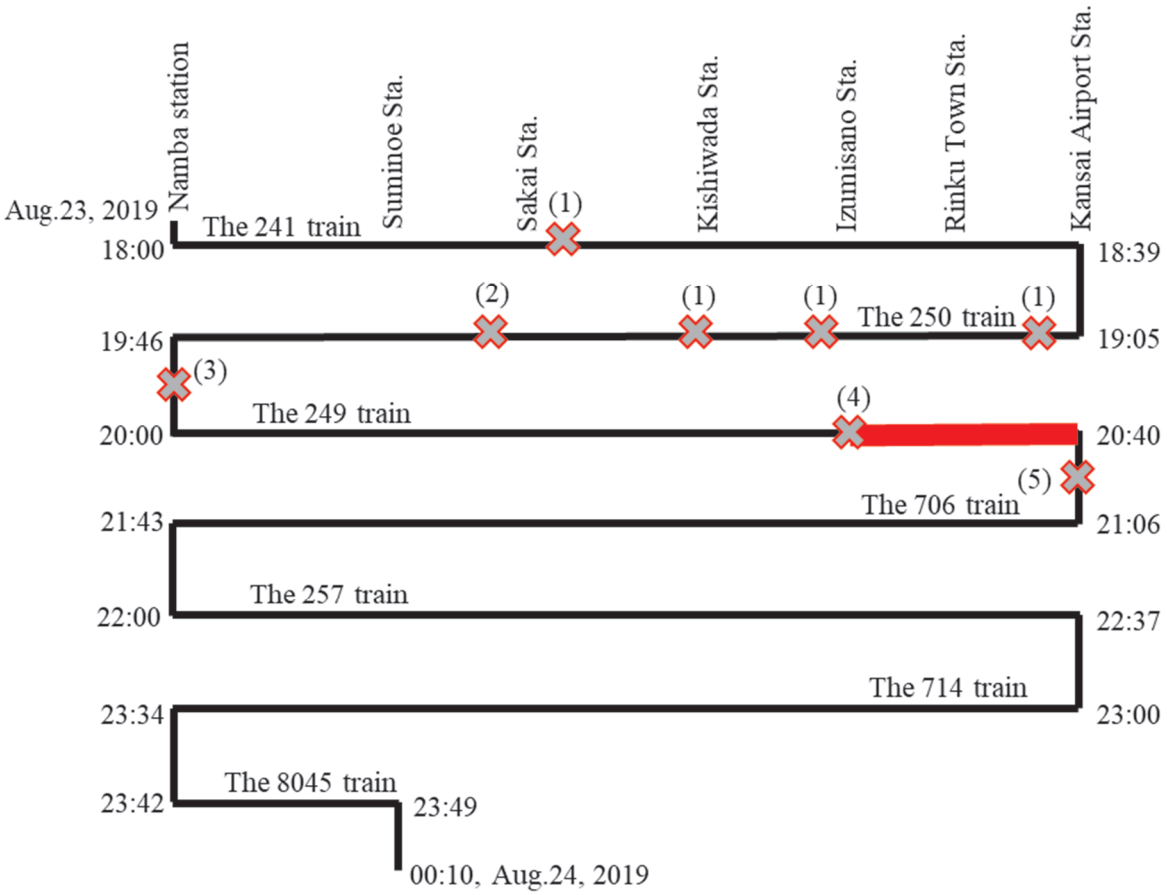
(3) On September 20, 2019, instructed the railway and tramway operators to report on the corresponding status against the notification of "Summary of study meetings of the state of measures related to railway transport troubles", July 30, 2018, and the corresponding status against the revision of "bogie frame inspection manual", July 30, 2018, as a confirmation of the corresponding status in light of the "Summary of study meetings of the state of measures related to railway transport troubles," etc.

Attached Figure 1. Route Map of Nankai Main Line and Airport Line

Nankai Main Line : Between Namba station and Wakayamashi station, 64.2 km
Between Namba sta. and Suminoe sta. is electrified triple & quadruple track.
Between Suminoe sta. and Wakayamashi sta. is electrified double track.



Attached Figure 2. Operation and Status of the Train from the Previous Day



(1) The conductor noticed the metallic sound as squeak corresponding to motion of vehicle from under the gangway footplate of the coupled part of the 2nd and 3rd vehicles when patrolled the cabins.

(2) The conductor reported to the dispatcher using train radio that "There is a defect in the vehicle. Loud sound as metals rubbing each other is heard from under gangway footplate of the connecting part of the 2nd and 3rd vehicles while running. Please contact with the relevant sections".

(3) The vehicle inspection dispatcher instructed Hagurazaki Vehicle Inspection Branch Chief to board on the outbound 249 train from Izumisano station to check the vehicles. Hagurazaki Vehicle Inspection branch Chief who received the instruction instructed the vehicle inspection staffs A and B to board on the train from Izumisano station.

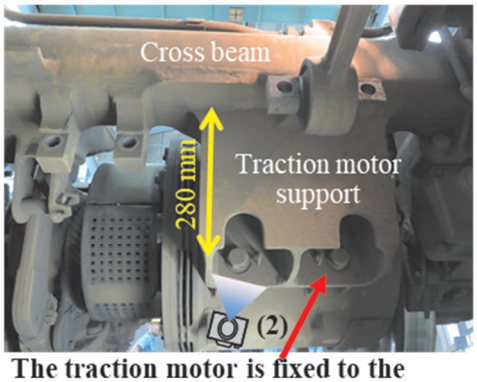
(4) The vehicle inspection staffs A and B of Hagurazaki Vehicle Inspection Branch boarded on the outbound 249 train from Izumisano station to Kansai Airport station as checking the sounds.

(5) As the vehicle inspection staffs A and B of Hagurazaki Vehicle Inspection Branch could not confirm any abnormal noise as a result of onboard inspection, reported by telephone to the chief of the Hagurazaki Vehicle Inspection Branch that "Any unusual noise was not confirmed".

The vehicle inspection dispatcher, who was reported from the Hagurazaki Vehicle Inspection Branch Chief that there was no abnormality, instructed to the Suminoe Vehicle Inspection Division that "There is a metallic sound while running from the coupling part between the 2nd and 3rd vehicles of the train. Please check the train when the train enters to a depot".

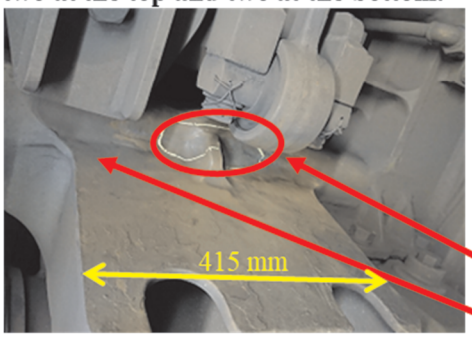
Attached Figure 3. Structure of the Bogie and Damaged Status

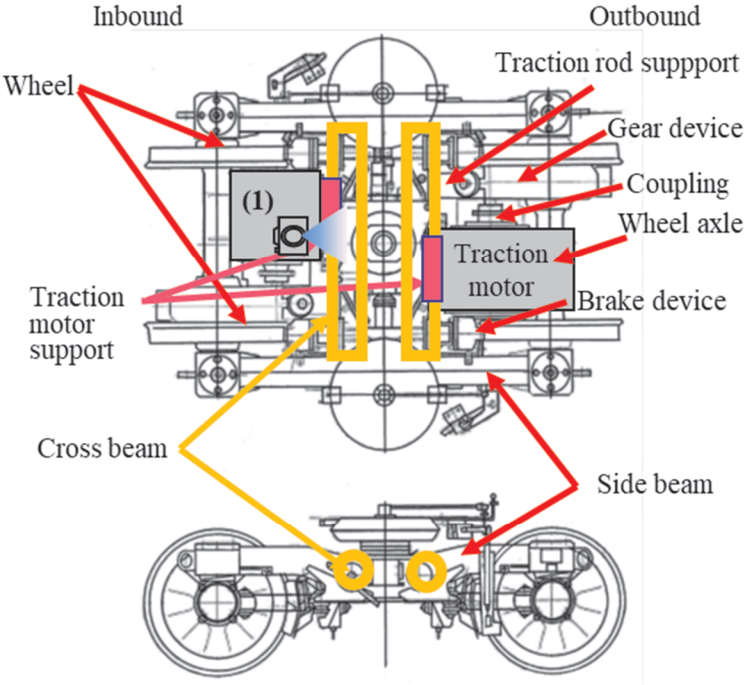
(1)



The traction motor is fixed to the traction motor seat with four bolts, two at the top and two at the bottom.

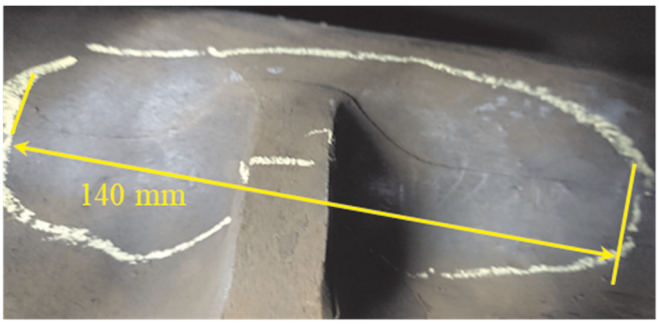
(2)



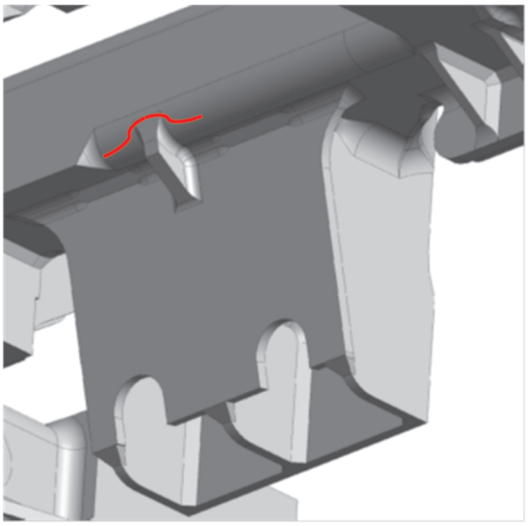


Concerned crack, reinforcing rib welded part.

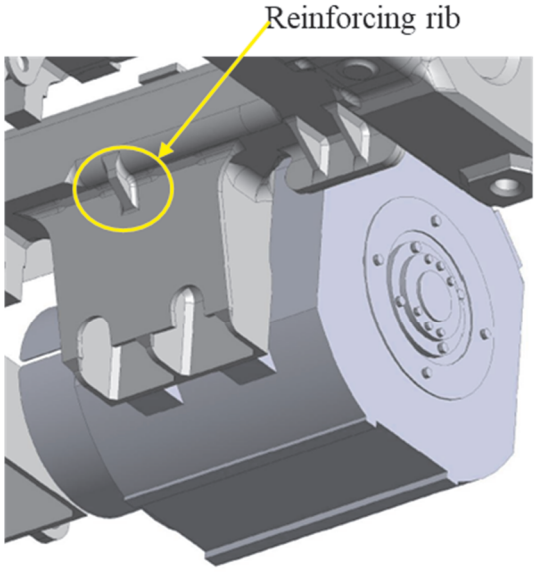
Traction motor support is welded on the cross beam



Enlarged concerned crack

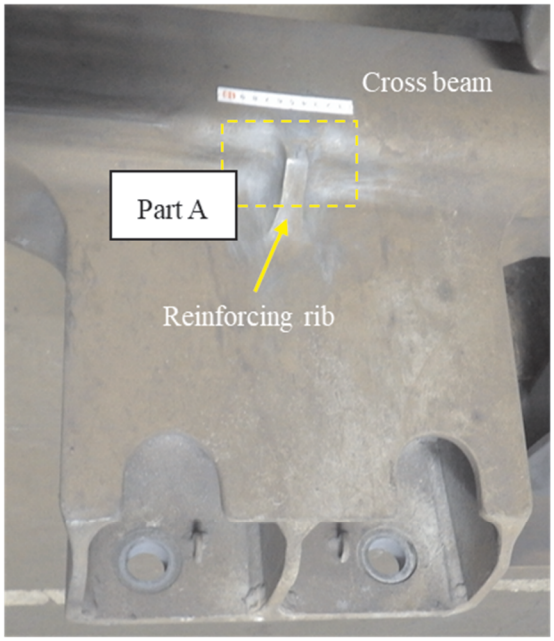


CAD drawing around concerned crack

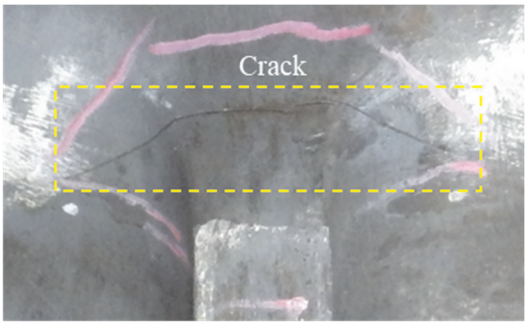


CAD drawing of traction motor and traction motor support

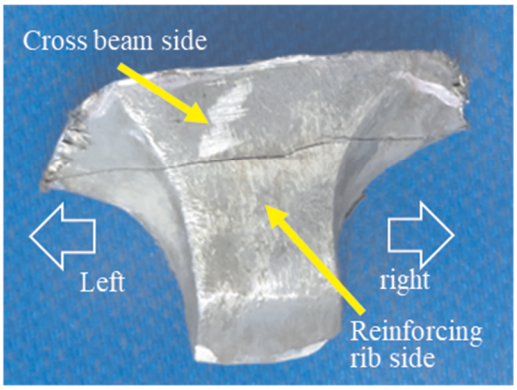
Attached Figure 4. Situation of the Broken Surface of the Crack, 2nd vehicle of the 5th trainset



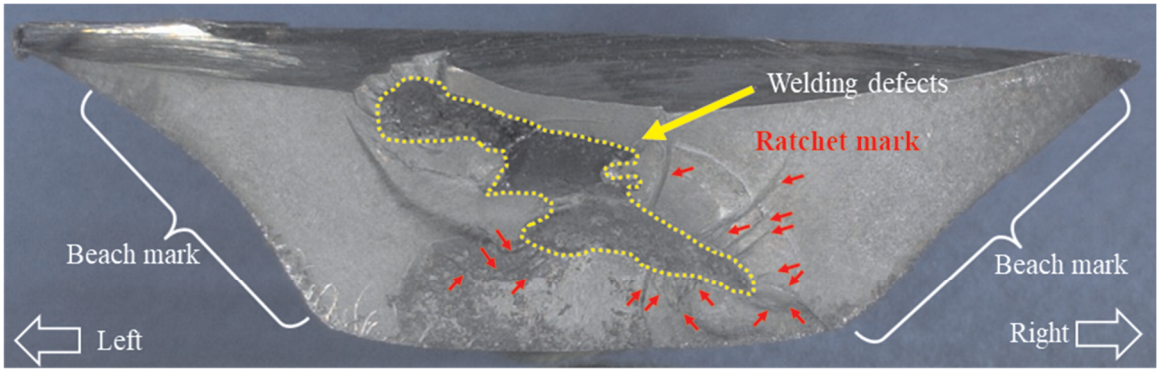
Cross beam and back of traction motor support



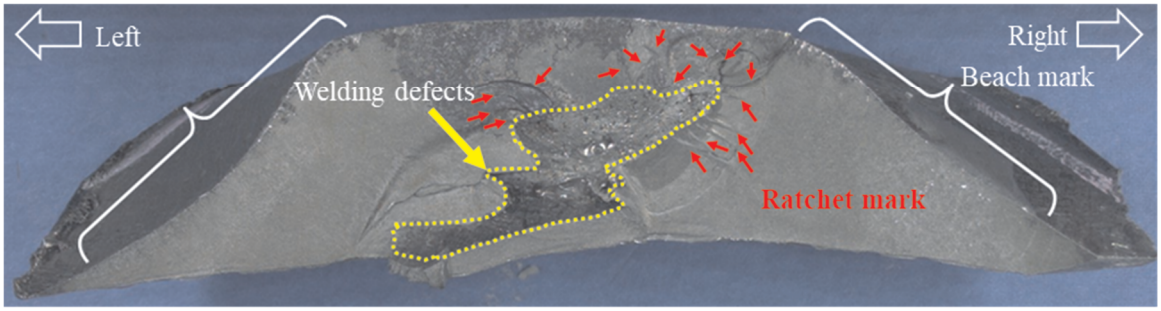
Enlarged view of part A



Appearance of cutout part



Appearance of broken surface of the reinforcing rib side



Appearance of broken surface of the side beam side

Attached Figure 5. Status of Abnormal Sound Generated Place