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Special Roundtable to Commemorate the 60th Anniversary of the Shinkansen's Inauguration

NOTE: This roundtable was held on June 27, 2024. The affiliations and positions of the participants, as well as the information mentioned in the text, are as of that date.

Introduction

Moderator: In 2014, the Railway Technical Research Institute (RTRI) published a feature article in our magazine, RRR, highlighting the technological advancements of the past 50 years since the Shinkansen's inauguration. Today, as we commemorate the 60th anniversary of the Shinkansen in 2024, I invite you to reflect on its progress over the last decade

and share your perspectives on its future development.

Hokuriku Shinkansen's Kanazawa-Tsuruga Section Opened

Moderator: It has been three months since the Kanazawa-Tsuruga section of the Hokuriku Shinkansen commenced operations. How are the ridership trends developing?

Tanaka (JR West): Indeed. The Kanazawa-Tsuruga section opened on March 16, 2024. During the first month, we recorded 723,000 passengers traveling between Kanazawa and Fukui, representing a 126% increase compared to the same period last year, with an average of 23,000 passengers daily. These figures significantly surpass both the 2023 numbers and those from 2019, prior to the COVID-19 pandemic. During Golden Week, the peak travel



Departure Ceremony at Tsuruga Station



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period in spring, we observed a 114% increase in passengers between Joetsu-Myoko and Itoigawa stations on the Hokuriku Shinkansen line compared to last year. Despite the ongoing impact of the 2024 Noto Peninsula Earthquake in January, the opening of this new section is positively contributing to the recovery and revitalization of the Hokuriku region.

Moderator: That is indeed encouraging news. Could you elaborate on the technical challenges and operational hurdles you faced prior to the opening?

Tanaka: A significant challenge was operating high-speed trains in heavy snow, particularly the unique moisture-

rich snow prevalent in the Hokuriku region while ensuring safe and stable transportation. To prevent snow accretion on vehicles, we designed the lateral ends of the bogie end cover plates with a snow cornice dummy structure. Furthermore, to mitigate ground damage from falling snow, we modified the wiring routes of the bonded conductors. These improvements were made in collaboration with the Japan Railway Construction, Transport and Technology Agency (JRRT) to address issues encountered after the opening of the new section.

Moderator: Mr. Santo, can you detail any new technologies JRRT implemented during the construction of the Shinkansen

infrastructure?

Santo (JRRT): We employed advanced civil engineering techniques to implement battered pile foundation viaducts with outwardly angled steel pipe piles. This configuration enhances seismic resistance in soft ground conditions and imparts vibration-damping properties to the tracks. During the development phase, we received substantial technical assistance from RTRI. We also adopted, for the first time, full precast viaducts, for



Fully Precast Viaduct



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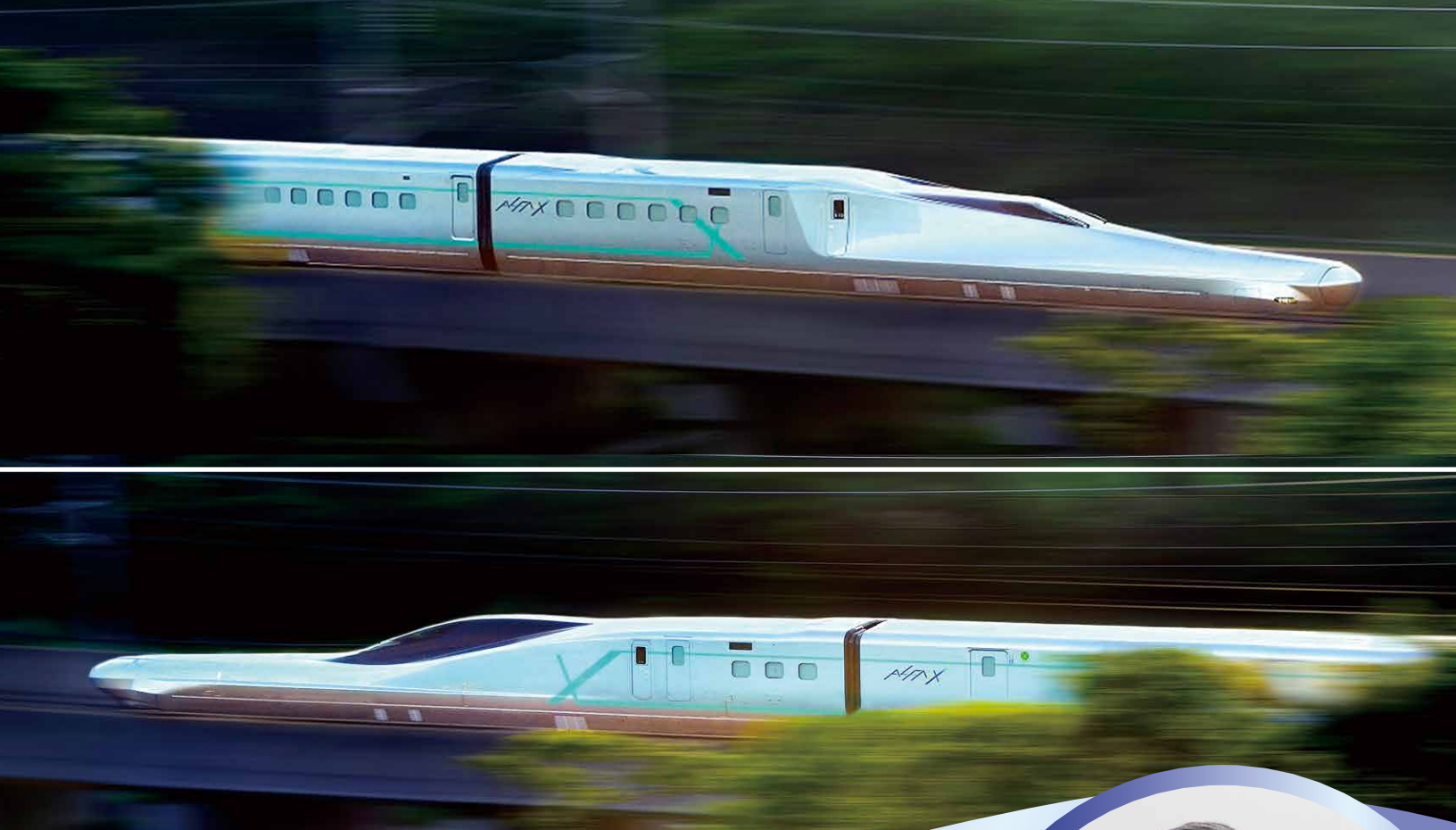
which components such as piers, beams, and slabs are manufactured in factories and assembled on-site. This approach shortened construction time and reduced labor requirements. I believe we have made significant pioneering efforts to enhance productivity in railway construction processes. Regarding electrical equipment, we implemented slip joint poles with varying diameters and thicknesses. The diameter of the upper ends of the thicker lower poles was reduced, whereas that of the lower ends of the thinner upper poles was increased, allowing the poles to be coupled together. By reducing the weight of the upper poles, we successfully created overhead catenary line (OCL) poles with enhanced earthquake resistance.

New Technologies Developed in the Last Decade

Moderator: JR East is actively pursuing technological development to increase Shinkansen speeds, including the development of the ALFA-X (Advanced Labs for Frontline Activity in rail eXperimentation) test train. Can you briefly discuss the current development status?

Tsukioka (JR East): With the ultimate goal of developing the next-generation Shinkansen for the future extension to Sapporo, we have implemented the E956 series ALFA-X test train. Our focus beyond high speed includes implementing countermeasures against earthquakes,

extreme cold, and snow damage. The test train was manufactured based on four key concepts: enhanced safety and stability, improved ride comfort, advanced environmental performance, and innovative and efficient maintenance processes. Currently, we are conducting research and development involving running tests and evaluating their results. ALFA-X test runs began in May 2019. We designated May 2019 to March 2022 as Phase I of running tests to assess the basic functions of the vehicles, focusing on speed



E956 Series Shinkansen Test Train ALFA-X

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improvement, environmental impact, braking performance, and ride comfort, primarily on the Tohoku Shinkansen line between Sendai and Shin-Aomori stations. Since April 2022, we have entered Phase II of running tests to verify durability performance and next-generation services.

Moderator: Can you provide examples of the items developed during these tests?

Tsukioka: To improve the safety and stability of the Shinkansen, we have developed several equipment and systems, including the aerodynamic drag plate unit and linear decelerators for rapid stopping

after an earthquake, anti-seismic dampers to reduce derailment risk, and a bogie sensing system for continuous monitoring of bogie conditions. To enhance ride comfort, we have developed anti-vibration devices and a vertical vibration suppression system. To improve environmental performance, we have implemented two nose shapes and low-noise pantographs to mitigate tunnel micro-pressure waves and noise. Currently, we are working on technologies that utilize data obtained from continuous monitoring of vehicle equipment and ground facilities for maintenance purposes, as well as basic railway technologies for future

automatic train operations. Additionally, we are collaborating with RTRI on several projects, including the development of the aerodynamic drag plate unit, linear decelerators, measures to prevent snow accretion using running wind, and the vertical vibration suppression system.

Moderator: JR Central's N700S series incorporates various innovative

technologies. Can you discuss some of them in detail?

Morikawa (JR Central): Launched in July 2020 as the first fully remodeled version since the N700 Series, the N700S features significant safety and stability improvements, including reduced braking distances in the event of earthquakes and enhanced condition monitoring through high-capacity data communications. Moreover, the N700S has achieved a 7% reduction in power consumption compared to the N700A Type by employing SiC device to the drive system—the world’s first for high-speed rail—to miniaturize underfloor component as much as possible and by implementing the Dual Supreme Wing design that reduces running resistance. Furthermore, we have achieved a standardized rolling stock design, which, based on the 16-car configuration design, allows for constitution to 12-car or 8-car formations. This was made possible by mounting the main transformer and power converter, previously installed on separate cars, on the same car. Additionally, we have enhanced ride comfort by using a fully active damping control system.

Moderator: From the discussion thus far, it is evident that various technologies have been introduced to reduce weight, conserve energy, and improve ride comfort. I understand that JR Central has also implemented a battery-powered self-propulsion system.

Morikawa: Indeed. We have pioneered a battery-powered self-propulsion system in high-speed rail, enabling trains to run itself during power outages. This allows trains to travel to a location where passengers can safely evacuate, even if they stop inside tunnels or on bridges. For the N700S series Shinkansen trains scheduled for launch from fiscal 2026 onwards, a new feature will be added to enable air conditioning

systems to operate with onboard batteries, which will significantly enhance the internal environment during power outages.

Moderator: What kind of technological developments has JR West been working on?

Tanaka: Since the December 2017 incident, which was classified as a serious incident by the Japan Transport Safety Board (JTSB), we have been developing systems for the early detection of bogie abnormalities. Specifically, for the Sanyo Shinkansen’s 500, 700, and 8-car N700 series, we have been developing methods to detect early signs of bogie bearing abnormalities. For the Hokuriku Shinkansen’s W7 series, we have been developing methods to detect early signs of abnormalities in bogie frames and gear devices. Regarding car bodies and electrical equipment, we are advancing initiatives to collect and analyze vehicle data transmitted wirelessly from running trains to monitor vehicle conditions from the ground. We are also implementing condition-based maintenance (CBM) strategies, including failure prediction by analyzing data related to pre-failure condition trends, enabling early-stage repairs; predictive detection, which compares operational status data for multiple components, such as side sliding doors and air conditioning units, to preemptively perform the necessary repairs; and alternative inspection techniques that utilize the most recent operational data instead of conducting on-site inspections.

Moderator: JR West has been actively utilizing artificial intelligence (AI), hasn’t it?

Tanaka: That’s correct. For instance, we have implemented wear-detection techniques for detecting arc erosion of pantographs caused by frost accretion on

OCls in winter. We also utilize AI to analyze images of pantograph heads captured while trains are stopped at stations and determine their condition (normal or abnormal). Machine-learning data are increasing year on year, thereby enhancing detection accuracy.

Moderator: Some of the technological developments introduced thus far were achieved in collaboration with RTRI. Can you detail any technologies that RTRI has jointly developed with other companies besides those already mentioned today?

Murono (RTRI): I would like to introduce the precipitation-hardened copper (PHC) simple catenary system. While the three-wire heavy compound catenary system has been used on conventional Shinkansen lines (Tokaido-Sanyo, Tohoku, and Joetsu), we have applied a new material—a PHC alloy—to develop a simpler, two-wire catenary system. This PHC simple catenary system, jointly developed by JR TT, JR East, and RTRI, combines high strength and conductivity to accommodate high-speed Shinkansen operations. By reducing the number of wires from three to two, maintenance is simplified. This system is being gradually adopted across the Shinkansen network.

Moderator: Please discuss the new technologies developed by JR TT over the past decade.

Santo: For the operations of the Nishi-Kyushu Shinkansen line and subsequent projects, JR TT has developed and implemented two key technologies. In civil engineering, we have introduced geosynthetic-reinforced soil (GRS) integrated bridges with a prestressed concrete (PC) structure, and in track engineering, we have implemented sleepers integrated slab track with under sleeper pads (USPs). We have also



N700S Shinkansen



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actively engaged in the digitalization of track construction work. This includes storing measurement data in on-site radio frequency identification (RFID) tags, allowing data retrieval through smartphones. Additionally, we have employed alignment sensors to adjust track slab installation alignment, replacing traditional track levelers. The tags embedded in the slabs have enabled the recording of the installation location of each slab. All data obtained

are consolidated into the construction information management system. Additionally, we have developed a train schedule management system and an integrated work management system to improve the on-site management efficiency of construction machinery and work crews.

Moderator: I understand that significant time and ingenuity have been invested in these advancements. RTRI's competitive edge lies in its simulation and measurement technologies. Can you

explain any new approaches adopted in these technical fields over the past decade?

Murono: Mr. Tanaka of JR West mentioned their countermeasures for cold regions. RTRI has also developed a method for estimating snow accretion and snow dropping from train vehicles. This method can estimate, in real-time, the amount of accumulated snow and the location where it drops off based on train operation data and weather conditions along the line. This information can be used to determine whether snow removal work is necessary on arrival at the station or identify priority sections requiring countermeasures. To provide an example of our R&D efforts related to noise-reduction measures, as mentioned by Mr. Tsukioka of JR East, we have independently developed a portable two-dimensional spiral array system with a microphone array. By applying the latest acoustic processing technologies

to the recorded data, we have enabled high-resolution identification of moving sound sources. This array system has sufficient spatial resolution to visualize the distribution of sound sources approximately the size of a wheel, allowing examination and demonstration of the effectiveness of noise-reduction measures for sound sources such as bogies and pantographs.

Countermeasures Against Natural Disasters

Moderator: Reflecting on the past decade, we have experienced major natural disasters, with the impression that numerous massive earthquakes have occurred. The 2024 Noto Peninsula Earthquake on New Year's Day is still fresh in our memory. Have you made significant progress in earthquake-related technologies?

Murono: Over the past decade, Japan has experienced over ten earthquakes with an intensity of 6 or higher on the Japanese scale of 0 to 7. It is believed that the Japanese archipelago has entered a period of increased seismic activity, raising concerns about the potential for major earthquakes in the future. In response, RTRI has been researching and developing countermeasures aligned with four phases of resilience against large-scale earthquakes: prior response, emergency response, initial response, and recovery response.

Moderator: First, please describe your prior and emergency response strategies.

Murono: Prior response refers to anti-seismic measures taken before an earthquake occurs. We have revised the technical standards for the anti-seismic design of structures, significantly enhancing seismic resistance. Newly

constructed Shinkansen structures are designed to satisfy safety and restorability criteria for earthquakes with an intensity of seven on the Japanese scale. The Shinkansen's earthquake resistance has been dramatically improved. We have also developed anti-seismic lateral dampers to prevent derailments. This new damper system exerts a high attenuation force to suppress car body vibrations during earthquakes, minimizing the chances of derailment. As an emergency response measure, RTRI has improved the immediacy of alarms and warning accuracy of our early earthquake warning system, which detects earthquakes and promptly stops trains. We have modified our P-wave processing methods and reviewed our noise identification techniques. Furthermore, in collaboration with the National Research Institute for Earth Science and Disaster Resilience (NIED) and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), we have developed an earthquake warning system utilizing an ocean-bottom seismic observation network and implemented it in cooperation with other JR companies.

Moderator: JR companies have also been actively working on prior and emergency responses for quite some time, haven't they?

Morikawa: JR Central has been improving the Tokaido Shinkansen through (1) anti-seismic reinforcement of structures, including steel plate wrapping on viaduct piers, sheet pile cofferdams for embankments, and ground reinforcing methods for embankments; (2) earthquake disaster prevention systems based on our seismometers, Earthquake Early Warnings (EEW) distributed by the Japan Meteorological Agency (JMA), and the ocean-bottom earthquake observation network of NIED; and brake performance improvement for promptly stopping

trains and (3) measures to prevent vehicle derailment and deviation.

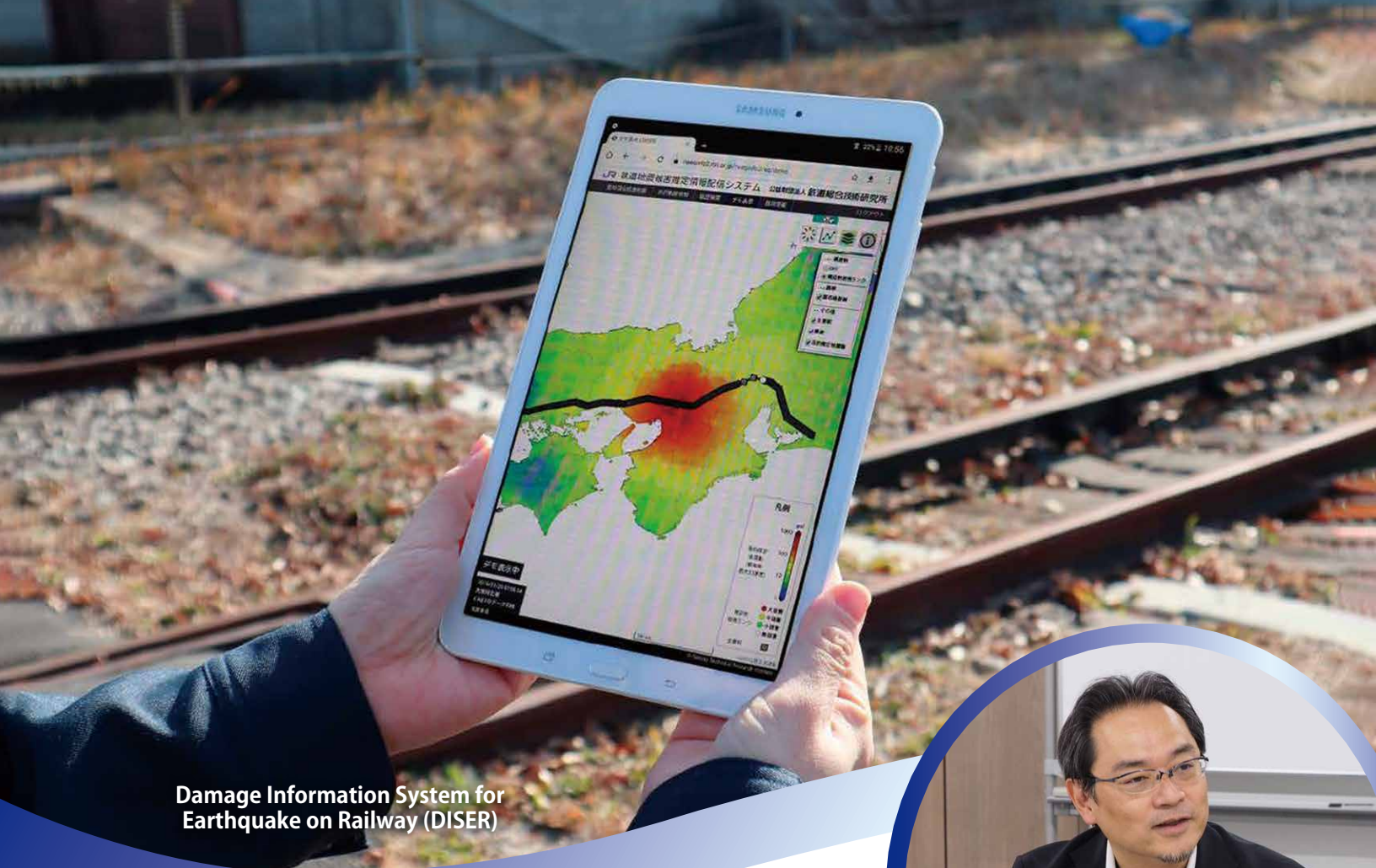
Tanaka: JR West has been similarly engaged in implementing anti-seismic measures, including the reinforcement of viaducts and poles for OCLs, early earthquake detection methods, and deviation prevention measures.

Moderator: Next, can you elaborate on developments regarding initial and recovery responses?

Murono: As an initial response measure, RTRI has developed the Damage Information System for Earthquake on Railway (DISER), which has been operational since 2019 and utilized by several railway operators. This system predicts ground motion intensity along railway lines and potential structural damage within minutes after an earthquake, disseminating this information to railway operators. By narrowing down the area requiring inspection, it reduces downtime until operations resume. Additionally, for recovery response, we have developed technologies that enable rapid service restoration. These include proposals of design methods that concentrate bearing damage on easily repairable locations and the development of embankment restoration techniques utilizing gabions, which do not require emergency repairs.

Moderator: In the 2022 Fukushima Prefecture Offshore Earthquake, a Tohoku Shinkansen train derailed, and JTSD released their findings regarding the cause. Can you share insights gained from this earthquake and discuss potential countermeasures?

Tsukioka: I believe that numerous vehicle guide devices functioned and prevented vehicles from significantly deviating



Damage Information System for Earthquake on Railway (DISER)



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from the track, which ultimately helped mitigate the severity of the impact. However, some wheelsets deviated because vehicle guide devices did not function as expected. Because derailment and deviation during operation can cause extensive damage, we have improved the shape of the interface of wheelsets equipped with fitting arms to enhance rail contact. This development is complete, and we are gradually implementing these improvements on commercial vehicles. Regarding the anti-seismic lateral dampers Mr. Muro no of RTRI mentioned, we are continuing development for their future implementation. In the 2022 derailment

incident, some air springs experienced excessive deformation, leading to air loss, which may have contributed to the derailment. Therefore, it is necessary to thoroughly investigate the impact of air springs on derailment and deviation scenarios.

Key Technological Advancements Required for Shinkansen Over the Next Decade

Hokkaido Shinkansen's Extension to Sapporo

Moderator: To conclude, let's discuss the

key technological advancements required for the Shinkansen over the next decade. The extension of the Hokkaido Shinkansen to Sapporo will be a major event during this period. First, how are the technical preparations for this extension progressing?

Tsukioka: To ensure the success of the Hokkaido Shinkansen's extension to Sapporo, we must develop technologies enabling safe and stable operations in the extreme low-temperature and

heavy snowfall conditions that existing Shinkansen lines have not encountered. Since the initial ALFA-X test run, we have conducted trials on the Hokkaido Shinkansen section every winter in cooperation with JR Hokkaido Railway Company, to evaluate performance under these conditions. As previously mentioned, we are continuously verifying the snow accretion reduction effects of heater-installed bogie end cover plates for suppressing snow accumulation in the bogie cavity and of the bogie covers designed for controlling snow accumulation using intakes that channel airflow into the cover. Additionally, we are verifying adhesion performance under low-temperature and wet conditions and developing activators to enhance adhesion.

Moderator: From your perspective as a construction expert, lowering construction costs is likely a significant challenge. How do you plan to address this?

Santo: Although not directly related to the Sapporo extension, I would like to share some of our company's findings. Last year, we established the Construction digital transformation (DX) Vision. Given the decreasing and aging workforce of skilled technicians and engineers, I believe that (1) mechanization and precast implementation of on-site construction work, and (2) streamlining construction planning and management through digital technologies will improve labor productivity and reduce costs. For example, in viaduct construction, we aim to standardize the on-site assembly of PC components manufactured in advance at factories. We are considering optimizing the entire design and construction management process by using AI to analyze big data related to quality control, work progress management, heavy machinery, and transport vehicles. We also

plan to collaborate with RTRI on building information modeling (BIM)/ construction information modeling (CIM), with the intention of applying these processes from design analysis through to maintenance management.

Digital and AI Technologies

Moderator: Mr. Santo just mentioned that digital technologies will improve labor productivity and reduce costs. I have heard that JR West actively utilizes digital technologies, especially AI. Please discuss some of JR West's latest applications of digital and AI technologies for the Shinkansen.

Tanaka: Regarding the utilization of AI technologies to save labor, in addition to the aforementioned AI-based image recognition system, we have developed and implemented a model for estimating snow accretion amounts on train vehicles. This model uses AI to determine the necessity of removing snow accumulated under the vehicles while trains are stopped at stations along the Hokuriku Shinkansen line. Currently, we are collecting data to construct a prediction model for the newly extended section to Tsuruga. Furthermore, we are working on improving operational efficiency by capturing images from the driver's cab and analyzing them at the depot in collaboration with train crews, thereby reducing the need for train and foot patrols. This is another example of our application of digital technologies. We are also advancing the automation capabilities of our working vehicles, such as those for maintenance or snow removal, and exploring the use of drones for inspecting infrastructure such as viaducts, retaining walls, and bridges.

Moderator: Each company seems to be promoting the use of AI in various ways. I would like companies other than JR

West to share their experiences regarding challenges encountered in implementing AI technologies.

Murono: Efforts are underway to automate tasks previously performed through visual inspection by using camera images enhanced with AI. However, AI is not infallible. When the AI system makes judgment errors, we must investigate the causes and address the inherent limitations of AI techniques. Moreover, without understanding the basis for AI judgments, it is impossible to determine the appropriate corrective measures. To address this, RTRI has developed a method for estimating the factors contributing to missed detections by AI in front-monitoring systems designed to detect obstacles in front of trains. This technique analyzes the root causes of false negatives in AI-powered obstacle-detection systems for railway applications. In our evaluations, we successfully identified the factors behind all overlooked instances. This technique can also be applied for performance verification during AI development and other similar purposes.

Automatic Train Operations

Moderator: In the wake of the COVID-19 pandemic and thereafter, developing labor-saving and unmanned systems for train operations and maintenance has become an urgent issue. One highly anticipated example is automatic train operation. What is the prospect of implementing such a system on the Shinkansen?

Morikawa: JR Central is working toward introducing Grade of Automation 2 (GOA2), an automatic operation system, for commercial operation on the Tokaido Shinkansen, which is characterized by long inter-station distances and a highly dense and complex timetable owing to

its numerous train services. Therefore, it requires train operations that ensure safety, punctuality, and passenger comfort while responding to factors such as speed restrictions, gradients, weather-related slowdowns, and emergency speed reductions for safety checks, all within this complex timetable structure. To achieve this, we have developed a highly functional Shinkansen automatic operation system that calculates train performance curves in real-time during operation, enabling efficient driving for energy conservation and enhanced ride comfort. Currently, we are conducting running tests of this system on the main line, aiming to gradually commence operations from around 2028.

Carbon Neutrality

Moderator: Next, please provide an overview of the carbon-neutrality initiatives undertaken by each company.

Tanaka: As part of our commitment to achieving carbon neutrality and realizing a decarbonized society, we have set the objective of net-zero CO₂ emissions for the entire group by 2050 as our long-term environmental goal. To achieve this, we are promoting the introduction of renewable energy sources for electricity procurement. By introducing electricity derived from renewable sources, such as solar power generation facilities, we expect that approximately 13% of the traction power for our entire Shinkansen network (1.43 billion kWh annually) will be from renewable sources by the end of fiscal 2027.

Tsukioka: As the demand for reducing environmental impacts continues to grow, particularly in pursuit of achieving the Sustainable Development Goals (SDGs), technologies aimed at CO₂ emission reduction are indispensable. These include reducing the weight of car

bodies, enhancing energy efficiency, and minimizing running resistance. Additionally, it is crucial to develop environmentally conscious technologies, including expanding the adoption of recycled materials with lifecycle awareness and reducing the use of materials that contribute to global warming.

Moderator: Speaking of recycling, JR Central is advancing development focused on vehicle recycling. Can you tell us about your company's initiatives in this area?

Morikawa: For vehicle manufacturing, we have established a process for sorting aluminum components from decommissioned vehicles and ensuring the reliability and quality of recycled aluminum as a car body material. This has enabled us, for the first time in Shinkansen history, to utilize recycled aluminum for Shinkansen car bodies, which require high strength. Moreover, for the N700S series scheduled for introduction from the fiscal 2026 onward, we intend to increase the application areas of recycled aluminum to approximately 1.6 times that of conventional Shinkansen trains, further reducing CO₂ emissions in the aluminum process for car bodies. We will continue to reduce the environmental impact of the Shinkansen by promoting technologies that contribute to CO₂ emission reduction, such as energy conservation measures.

Integrated Approaches to Common Challenges

Moderator: We have all shared specific initiatives of each company, and there appear to be many common challenges. How do you perceive these trends and how will RTRI consolidate these findings for future research and development?

Murono: While many technical challenges are common across companies, we believe

it is crucial to advance technological innovation through collaborating beyond organizational frameworks and by standardizing and sharing technologies. This approach can reduce development costs and time, and equipment standardization will ensure a smooth supply from manufacturers. With this in mind, RTRI is developing rules and platforms to share technical information and data, such as images of track infrastructure and wayside equipment. Currently, each railway operator collects data and conducts development individually, which limits collection conditions and the volume of image data and requires considerable time and effort. I believe it would be beneficial to establish a foundation for railway operators to share image data, common processing technologies, and evaluation data.

Conclusions

Moderator: Today, we had the opportunity to explore each company's initiatives in developing and improving various Shinkansen technologies and anti-seismic measures over the past decade. Reflecting on today's roundtable, it is evident that all companies have consistently incorporated innovative technologies to enhance passenger comfort and promote labor-saving measures, while constantly prioritizing safety. The exchange of views on future challenges has made this a particularly fruitful discussion. I sincerely hope that we can continue to collaboratively develop the Shinkansen network, which serves as the backbone of our national infrastructure while adapting to societal changes. Thank you all for your participation today.