New Developments in Next-Generation Shinkansen Research — New E956 Series Shinkansen Prototype —

Yoshihiro EDO
Chief Researcher,
Advanced Railway System Development Center,
Research and Development Center of JR East Group,
East Japan Railway Company

Osamu KAWAKAMI
Principal Chief Researcher,
Advanced Railway System Development Center,
Research and Development Center of JR East Group,
East Japan Railway Company

Summary

In November 2016, East Japan Railway Company (JR East) announced its "Mid-to-long Term Vision for Technological Innovation" including "Research and development toward a next-generation Shinkansen." The concept is to attain a high level of safety, stability, comfort, a lower environmental burden, and greater ease in maintenance. Accordingly, we have decided to build a new high-speed test train for the Shinkansen as an experimental platform for to embody the concept. This train will be developed with the extension to Sapporo and legacy of present trains in mind.

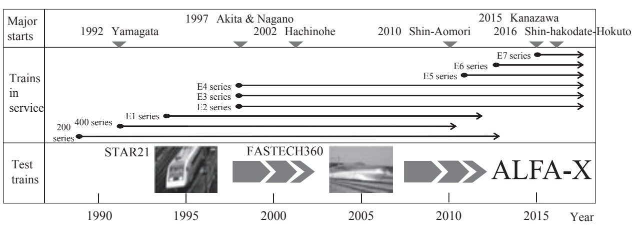
1. Back ground of Shinkansen speed up[1, 2)]

The Technical Development Dept. has a universal issue when increasing the speed of Shinkansen. Our development Shinkansen trains started with a test for running the 400 series at high speed (up to 345.8 km/h) in 1991. It was followed by test trains called STAR21 and FASTECH360 that recorded higher speeds. We have not only shortened travel time but also enhanced other railway-related technologies, and have increase safety, decreased noise levels, and improved riding comfort.

2. Change in test train for Shinkansen (Figure 1)

(1) STAR21

The concept for STAR21 was to develop an extremely light weight and high speed train using many technologies. A running test was conducted from 1992 to 1998. During the test, the test train recorded a maximum speed of 425 km/h. STAR21 helped develop environmental technology significantly, and the resulting weight reduction and main circuit technologies were used in succeeding trains now in service. In addition, we were able to reveal issues in high-speed rail not only related to vehicles but also other fields, such as tracks, power, signals, and earthwork, and undertook work on these issues.



	STAR21	FASTECH360	ALFA-X
Test period	1992-1998	2005-2009	From 2019
Concepts	To develop an extremely light weight and high speed train using many technologies	To raise express performance of trains in service, to attain top-level reliability and comfort, and environmental friendliness	Safe and high-speed transportation means and new values
Maximum speed during testing	425 km/h (Record)	398 km/h (Record)	About 400 km/h

Fig. 1 Evolution of our Shinkansen and concepts of test trains

(2) FASTECH360

JR East developed FASTECH360 with no particular aim of breaking the maximum test speed recorded in the past, but rather according to the following concepts: to raise the express performance of trains in service, to attain top-level reliability and comfort, and environmental friendliness. Running tests were conducted from 2005 to 2009. The test train improved in running performance and reliability, and contributed to the improvement of environmental performance and comfort, resulting in the E5 and E6 series running at 320 km/h, the highest service speed in the country.

3. New developments in next-generation Shinkansen research

(1) Concepts in developing next-generation Shinkansen

JR East is developing this next-generation train with extension to Sapporo by Hokkaido Shinkansen in FY 2030 in mind. We believe it is essential to give customers not only a safe and high-speed means of transportation but also new values for taking advantage of extra time had during long-distance travel, for them to enjoy the experience. We use the concept of "extra time" to contrast with the travel time of aircraft. To be specific, travel by air generally requires several changes in transport modes before arrival at a destination. As a result, the time the customer spends is broken into short pieces. Train travel in general allows users more available time.

Therefore, we aim for high-level safety, stability, comfort, environmental performance, and maintainability combining the AI technologies of IoT and big data analysis. Our plan includes linking research results to the next service - a new train for Shinkansen - and using them to raise safety and reliability levels in turn (Figure 2).

The following is an in-depth description of the concepts of research and development toward the next-generation Shinkansen.

a. Safety and Stability: - to achieve greater safety and stability -

JR East gives top priority to safety. To bring it up one notch, our aim is to accomplish ways to stop trains more quickly and safely when an earthquake occurs, and to have train cars carry out autonomous checks on the soundness of key parts. In addition, we desire to raise the level of stability through higher resistance to snow and cold and enhance failure prevention by detecting signs from vehicle and ground monitoring data.

b. Comfort: - meeting diverse needs -

Customer needs vary, so we must be flexible in meeting them. As mentioned before, customers want to spend available time comfortably; to concentrate on work, or to enjoy the train ride with their families. We plan to respond to such needs flexibly. We also aim to meet demand for a quieter and smoother ride and timely arrival at destinations.

c. Environmental Burden:- to minimize environmental burden -

Our noise reduction technologies have been developed to suppress noise when trains run at high speed. We also promote energy conservation through various technologies.

d. Ease of Maintenance: - to reform maintenance -

We are promoting CBM (Condition Based Maintenance) as a way to innovate maintenance of Shinkansen on-board and on-ground equipment.

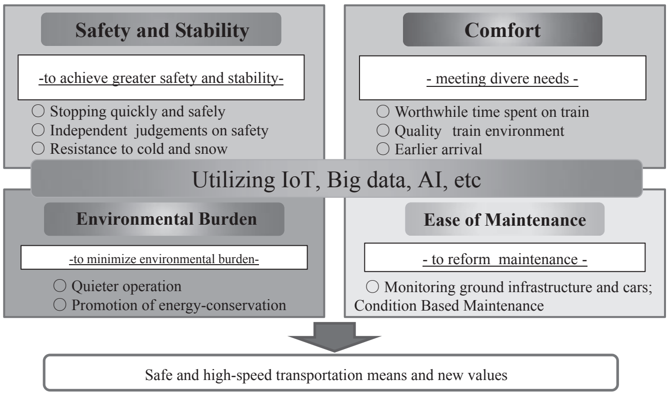


Fig. 2 Concepts of R&D for next-generation Shinkansen

(2) Structure of the test train

As an experimental platform to accomplish the development concepts mentioned in the previous section, we decided to build a new high-speed Shinkansen test train for prolonged use into the future.

(a) Series and maximum train speed

The new test train is E956 series, consisting of ten cars. The maximum speed during testing will be about 400 km/h and the train will be completed in the spring of 2019.

(b) Nickname of the test train

We decided to call the test train ALFA-X. This means "**A**dvanced **L**abs for **F**rontline **A**ctivity in rail e**X**perimentation."

(c) Features of the test train

Figure 3 shows images of the new test train. The following is a description of its features according to concept.

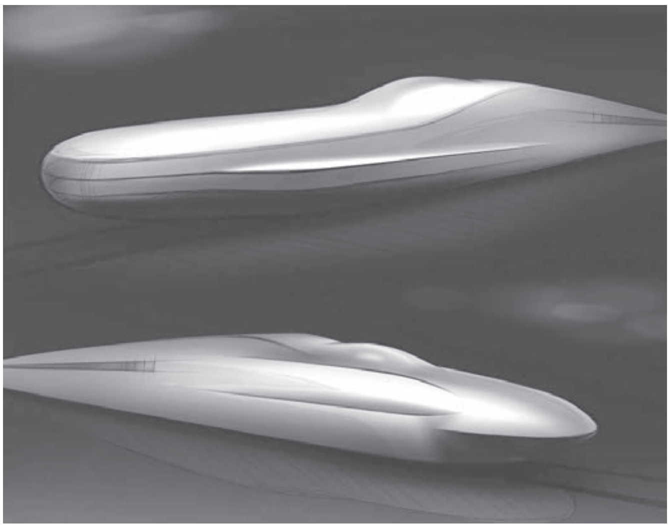


Fig. 3 Illustration of test vehicle (upper: Type A; lower: Type B)

1) Safety and stability

As earthquake measures, the test train has two kinds of devices to be developed to avoid derailment: one is a damper moving laterally and the other is a crushable stopper. The former works as an ordinary damper normally moving right and left, but when an earthquake occurs and severely shakes the train laterally, this exerts strong damping force to suppress the shaking train. When the test train receives a seismic shock, the stopper is pressed. As a result, the space between the center pin and stopper spreads to mitigate the shock between the body and bogie and to prevent high lateral pressure from occurring between the wheel and rail (Figure 4).

For a quick stop in the occurrence of an earthquake, the current train has only the mechanical brake (consisting of a brake disk, caliper, and lining) that relies on the adhesive force between the wheel and rail. To improve the high deceleration brake, we are working on a non-adhesive deceleration system that compensates for lack of braking force at high speed to shorten the stopping distance. One candidate is an "air-resistant-plate unit" that breaks the air resistance enhancer installed in FASTECH360 into small pieces. Compared with FASTECH360, the new test train holds a large advantage thanks to consisting of small units distributed throughout, taking up less space inside the train (Figure 5).

In addition, we conduct other activities for improving safety by monitoring the on-board devices and letting their safety-related parts make autonomous decisions based on conditions.

For more dependable transportation, we plan to install devices with greater resistance to snow and cold. We also plan to improve transportation quality by monitoring various devices to detect any failure signs and to prevent trouble from occurring.

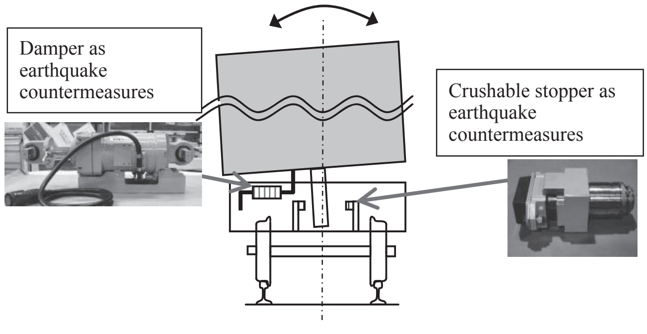


Fig. 4 New device to reduce the risk of derailment

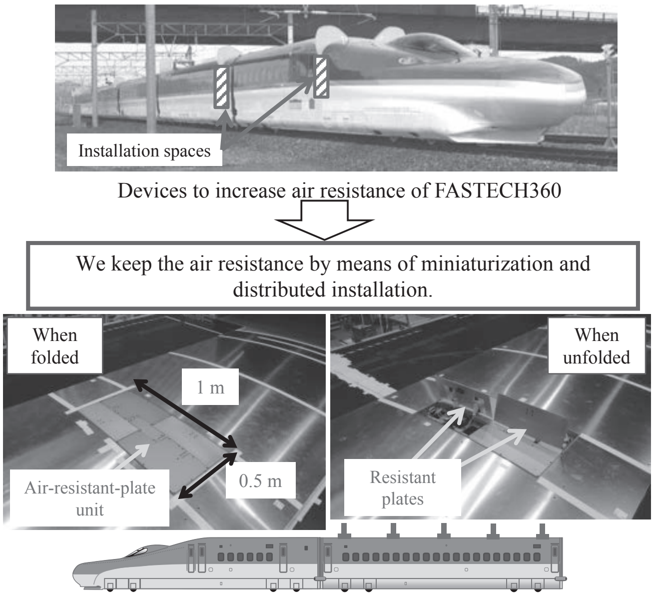


Fig. 5 Device to be developed for stopping the train more quickly (images of the air-resistant-plate unit installed)

2) Comfort

E2 series Shinkansen was the first train in service that had a pneumatic actuator working as a fully active controller that mainly reduced lateral shakes. In E5 series Shinkansen, JR East changed the actuator to a motor-driven type to improve response and control power. We plan to introduce a fully active controller with higher performance and a body tilt controller to the test train. We will also install a new controller against vertical for a "shake-free" train. For calm and quality in-vehicle space by we will add high sound absorption and insulation to the body structure (Figure 6).

To meet demands for express performance - quick arrival at destination, we will establish technology for running the train stably at 360 km/h.

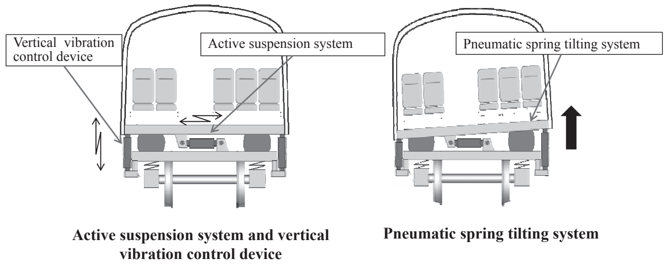


Fig. 6 Anti-vibration control devices

3) Alleviating the environmental burden

For quieter running, we are working on measures against noise and reducing pressure waves that occur when a train goes into a tunnel.

For this, we aim to reduce noise generated from the lower part of the body and the pantograph. Figure 7 presents examples of measures. When the brake disk turns during running, aerodynamic noise occurs. We are working on how to reduce such noise by reviewing the fin shape on the back of the disk. Concerning the pantograph, we make a simulation and wind tunnel test to develop a new pantograph that can reduce the resulting aerodynamic noise.

As for measures against the pressure waves in a tunnel, we plan to verify two new shapes for the head car of the test train. As shown in Figure 3, Type A has a nose longer than that of E5 series Shinkansen. In Type B, we plan to keep the in-vehicle space and to design the nose to reduce pressure waves.

To save energy, we will reduce the power conversion loss by improving the efficiency of equipment. For example, energy consumption efficiency can be raised through optimal drive control technology and SiC (silicon carbide) semiconductors for the power converter in driving.

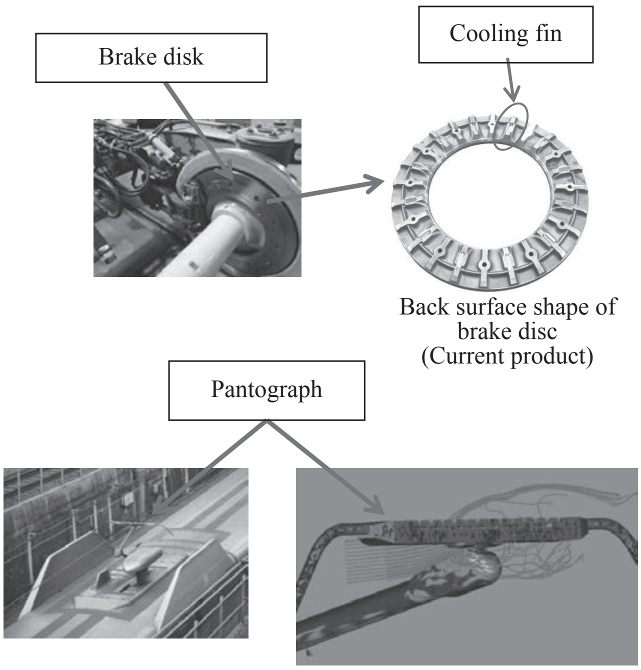


Fig. 7 Noise reduction mechanisms in the lower part of the vehicle (upper figure) and the pantograph (lower figure)

4) Ease of maintenance

JR East already conducts a variety of activities for CBM on the conventional lines and Shinkansen. In the latter, we promote such activities further by using the test train as an experimental platform. We aim for safer and more stable transportation by adding devices that monitor on-board and ground equipment to acquire and analyze data for maintenance reform (Figure 8).

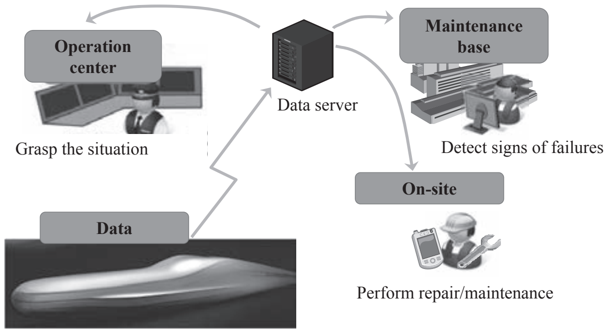


Fig. 8 Illustration of CBM

To achieve the goals above by using IoT, big data, and AI, we are working on how to enhance the on-board information and control network of the test train and to make it stronger than that of E5 series.

4. Conclusions

Currently, we are conducting a variety of studies and designs to complete the high-speed test train for Shinkansen by spring of 2019. For the next-generation Shinkansen of the "mid- to long-term visions of technical Innovation," we would like to build an intelligent train with high-level safety, stability, comfort, environmental performance, and maintainability. Therefore, we need cooperation from outside organizations, such as manufacturers and research institutes, to move forward on this project together with not only our R&D departments but also the headquarters, branches, and on-site facilities, all working as one beyond technical barriers.

[References]

1) Koji ASANO, "Evolving Shinkansen Technologies - Development of Shinkansen in JR East -," JREA, Vol. 60, No. 5, 2017 (in Japanese).
2) Koji ASANO, "JR East's Development of High-Speed Vehicles," JR EAST Technical Review, No. 57 (in Japanese).