Special feature article

Challenge of Fastech 360

Aiming for Additional Evolution of the Shinkansen

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1 Introduction

JR East's Shinkansen network comprises of a total of five directions starting from Tokyo, providing approximately 1,300km of high speed rail infrastructure. The network is comprised of three railways, Tohoku, Joetsu, and Nagano Shinkansen, and also includes direct service between conventional and Shinkansen tracks for Akita and Yamagata/Shinjo. As a result, a large number of the major cities in the east Japan area are connected by Shinkansen service.

The Shinkansen yearly traffic volume for JR East was 12.1 billion passenger-kilometers in 1987. In 2003 the number of passenger-kilometers increased to 18.7 billion, a 55% increase. Furthermore, the Shinkansen earnings increased by 49%, from 311.8 billion yen to 466.0 billion yen, and making the Shinkansen an important part of the foundation of the railroad business, establishing superiority for high speed travel.

JR East has developed new Shinkansen train cars to accommodate the five direction Shinkansen network. Examples of the new train cars are the E2 series,the E3 series designed for direct service between conventional and Shinkansen tracks, and E4 series which use double-decker cars for all cars to increase the number of seats to the maximum possible in commuting to the capital region. Further extension of railroad tracks is planned and competition with airlines will heat up even further. A further increase in speed, which in turn provides reduction in time required to reach destination is required to achieve competitive superiority. In addition, improved safety, compatibility with the environment, and increased comfort are also sought after.

Therefore JR East is proceeding with a research and development project targeting the establishment of high-speed technology enabling operation at a maximum speed of 360 km/h.

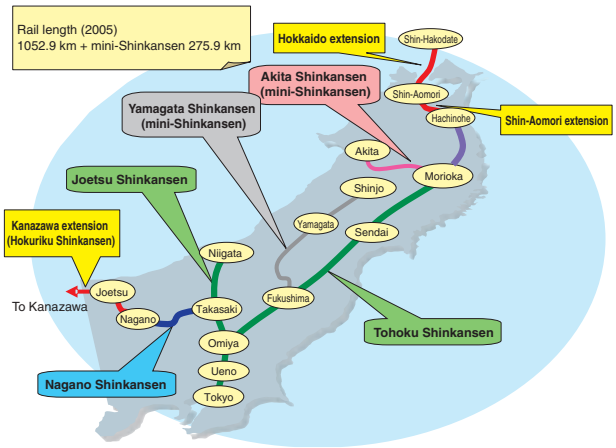

Fig.1: East Japan Shinkansen Network

2 Targeting additional increase in speed

From the correlation of data collected worldwide regarding the amount of time required for high speed railways compared with the market share for railways (compared to airlines), it is clear that reduction of amount of time required is a clear factor in achieving high market share. For example, in France, when the TGV high-speed operation from Paris to Marseille was achieved shortening the amount of time required from just over 4 hours to 3 hours, the railroad market share jumped to approximately 60% (from its previous level of just under 40%).

The Tohoku Shinkansen line is being extended to Shin-Aomori and the Hokuriku Shinkansen line is being extended to Toyama. In addition, extensions to Hakodate in Hokkaido and Kanazawa in the Hokuriku region have been decided and work on them has been started. When the Shinkansen extension to Shin-Aomori is complete, the distance between Tokyo and Shin-Aomori will be approximately 670 km. Currently, the railroads hold roughly 67% market share (FY2004) of travel between Tokyo and Aomori compared to airlines (both Aomori and Misawa airports) and in order to further increase railroad market share, an additional reduction in the amount of time required is needed.

Of course, train car performance, the condition of various facilities, safety, environmental compatibility and cost-effectiveness must be investigated to select the level of maximum operating speed to push for. Furthermore, the amount of time required is also affected by

conditions such as speed on curves, deceleration and acceleration speed, and stations stopped at. It follows that both business and technical standpoints must be considered for making a final decision. However, establishing of high-speed technology for Shinkansen at 360 km/h level is not feasible overnight. In addition, implementation of research and development with clear goals is important for prioritizing future Shinkansen business strategies as well as providing various selections.

Furthermore, technology enabling high speed is advanced through implementation of innovations in all fields such as train cars, tracks, electrical power, signal communication, civil engineering structures, operations and maintenance, and balancing the system configuration. Therefore, the continuous engagement in technical development to enable higher speed includes Shinkansen safety and compatibility with the environment, both of which are necessary for future evolution to a higher level.

3 Concept for the next generation Shinkansen

In order for the Shinkansen to gain popularity and have superior competitiveness as a high-speed transportation there are several necessary conditions that must be considered.

First is the assurance of safety and reliability. These are fundamental conditions required for high-speed railroads. Furthermore, consideration must be given for unexpected events, such as the Niigata-chuetsu earthquake, and it is essential that countermeasures are set in place to allow the realization of ultimate safety.

Second is the pursuing of reducing of time required for traveling to cities long distances away through implementation of high speed traveling with improved stability. This is the basis for competitive power for transportation.

Third is harmony with the environment. It is essential that noise and vibration generated through running be suppressed below permissible levels. From a certain perspective it can be considered that countermeasures for these issues hold the keys to future increases in speed.

Fourth is the improvement in comfort. Superior quietness and comfort inside cars even while running at high speeds are fundamental requirements for vehicles, and reaching a destination in a relaxed manner is a point where railroads are superior to both airlines and automobiles.

4 Outline of development for increasing Shinkansen speed

JR East is targeting implementation of increased speed for the Shinkansen and has established the "Shinkansen High-Speed project". The development of increased speed technology is primarily being promoted at Research and Development Center of the JR East group. Figure 2 shows the “Shinkansen speed increase project promotion process”.

At the outset, the knowledge accumulated in the past with respect to increasing Shinkansen speed was organized, the development issues

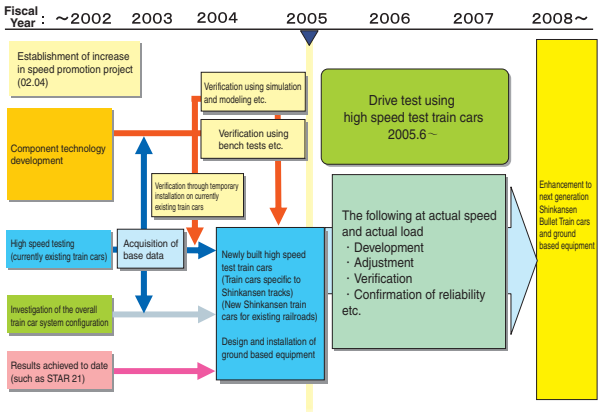

Fig.2: Shinkansen speed increase project promotion process

that need to be met for implementation of a new goal were extracted from all areas, and development of component technology was pushed forward. Component development started with computer analysis and simulation, and performance and durability testing were repeated for device and part level testing, as well as at the prototype biggie and prototype structure. Furthermore, in order to obtain high speed running data for current train cars and equipment to contribute to component development, 320 km/h to 360 km/h high-speed tests were performed using E2 series and E3 series train cars on the Joetsu and Tohoku Shinkansen tracks.

In addition, the achievements obtained through component technology development were collected for the train car system, and the Shinkansen high-speed test train car “Fastech360” was completed. In order to perform overall evaluation and verification of the running stability, effect on ground facilities and environment, and comfort in train cars, drive tests started on the Tohoku Shinkansen tracks on June 25, 2005. Sections where high speed testing is being performed are shown in Figure 3.

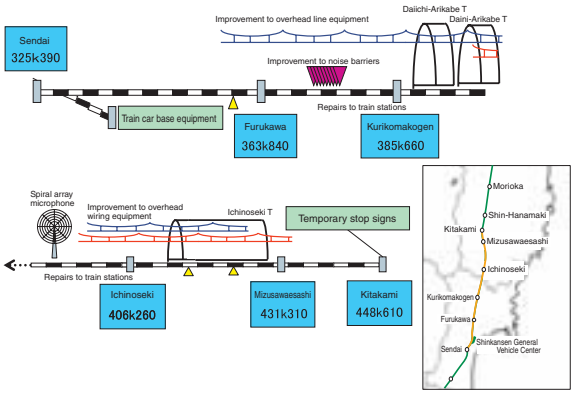

Fig.3: High speed running test sections (Sendai - Kitakami)

5 Technologies of the Shinkansen high speed operation test train car Fastech 360S

5.1 Formation summary

The Shinkansen high-speed test train car Fastech 360S (type E954) completed as described is a train car developed specifically for Shinkansen tracks.

The Fastech 360Z (type E955), a Shinkansen train car for direct service between conventional and Shinkansen tracks, is currently being worked on and is scheduled to be complete next spring. For the Tohoku Shinkansen line, direct service between conventional and Shinkansen tracks are in place for trains bound for Akita and Shinjo (Yamagata). It is therefore essential to run both types of train, making it necessary to for both types of high speed line to be operable. This is the reason for the development of two types of test train cars.

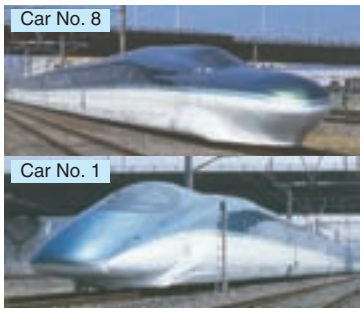

Fig.4: Fastech 360S lead train car shape appearance

The Fastech 360S is an 8-car train; both lead train cars have a 16 m long nose with considerably different shapes. Figure 4 shows the appearance of both of the lead train cars of the group of cars. The group of cars has 6- traction cars and 2-trailer cars giving a 6-traction 2-trailer group of cars. The maximum operating speed is 360 km/h, and, it has been designed to perform at a maximum speed of 400 km/h.

5.2 Improvement to running speed

The noise caused by the current collecting system makes up a large part of the noise generated along the railway due to running at high speed. Currently E2 series 10 car groups have been equipped with 2 pantographs. We aim to develop the current collecting system by using one pantograph for targeting noise reduction. In order to achieve this, a pantograph with a multi-segment slider that has high performance of following the overhead contact line and reduces aerodynamic noise has been developed. Furthermore, through weight reduction of the trolley wire and increase in tension, an increase in the wave velocity of overhead line equipment was achieved.

In order to configure a main electrical circuit system that can operate stably at 360 km/h, development of main power circuit devices (main power converter, traction motor, and power transformer, which have had size and weight reduction enhancements and high power output was pursued. In this case, innovations were implemented to contribute to reduction of noise both inside and outside the train car. Specific innovations were a main power converter cooled by ram air cooled water, self-ventilated synchronous motor driving, and a power transformer cooled by ram air. The above mentioned 3 types were developed for the main power circuit, and 1 unit of each type was installed for every two cars.

5.3 Ensuring of safety and reliability

When running at 360 km/h, acceleration vibration of the running gear increases, thus increasing the load on the axle bearings, and driving device and all of the components on the bogie. Here, axle bearings compatible with high speed, and a driving device that is highly reliable and produces low noise were developed. A prototype bogie equipped with these pieces of equipment was tested using bogie test equipment at Research and Development Center of the JR East Group, and a durability test that equalled 600,000km was performed at approximately 400 km/h to confirm reliability.

With respect to high speed running, the current brake system is basically sufficient. However, it is predicted that the life will be reduced through wear and thermal deformation of the brake discs and lining that form the base brakes. Here, in addition to introduction of new material for the discs and lining, the mounting method etc. for the discs was changed, enabling a great improvement to the base brakes.

In the north-eastern area of Japan, a lot of snow falls during the winter season. Snow adheres to the Shinkansen train cars while they are running, which hardens into blocks of ice that fall off again when the Shinkansen returns to the southern areas, scattering balast and causing damage. With the increase in speed it is predicted there will also be an increase in damage. Therefore, countermeasures have been introduced to make it harder for snow to adhere to the bogie and under the floor.

During emergencies such as earthquakes, the ability to stop as quickly as possible is the most important thing for reducing risks. Therefore, for the Fastech 360S, in addition to enhancing performance of the base brakes, the train cars were equipped with air resistance plates for increasing air resistance on their roofs for slowing the train cars.


Fig.5: Equipment for increasing air resistance

5.4 Harmony with the environment

The main issues with pursuing increase in Shinkansen speed are countermeasures needed for noise and vibration generated along the tracks. Japan has one of the most stringent noise standards in the world, and new environmental measures will be needed for both train cars and ground facilities in order to achieve further increases in speed.

When it comes to noise countermeasures, first, the source of the sound needs to be identified and this needs to be reduced to the minimum amount possible. Sources of noise can be classified into pantograph noise, aerodynamic noise from the train nose, aerodynamic noise from the upper parts of cars, and noise from the lower parts of cars including structure-borne noise.

Pantograph noise accounts for a large portion of this noise. As a countermeasure for reducing this noise, in addition to switching to only one pantograph, 2 new models of pantograph that reduce

aerodynamic noise even further have been developed. For one, the main frame is a single-arm type pantograph, and the other is a <-shaped arm type pantograph. and both types have under frames that have been streamlined. Furthermore, in order to further reduce pantograph noise, about 7 m noise insulation plates have been placed on both sides of the pantograph. (Fig. 6)

○New type low noise pantograph

Fig.6: Reduction of pantograph noise

Most train tracks have a noise barrier as a countermeasure for transmission of train car lower area noise; however, this does not eliminate all the noise, the noise repeatedly bounces back and forth between the noise barrier and train car(s), diffracts and attenuates at the top of the wall and leaves the train track area. Here, through attaching noise absorbing material to the lower external surfaces and bottom surface, noise that is reflected from the railroad track and noise barriers is absorbed enabling a reduction in the amount of noise that leaves the train tracks.

In order to reduce aerodynamic noise from the upper sections of the train cars and the lead cars, perfect smoothness of the roof, sides, and lead cars becomes necessary. Especially, smoothing of the joints between cars all around is effective and in order to achieve this, a metal hood for use between cars with an integrated link mechanism was developed and is being used for the entire train.

When the Shinkansen enters a tunnel, it generates a compression wave that travels through the tunnel at the speed of sound and generates a shock wave at the tunnel exit. Countermeasures for this include optimization of the shape of the lead train car and entrance hood at the tunnel entrance. In the case of further increase in speed, the micro-pressure wave must be suppressed to the current level or lower. Therefore, for the Fastech 360, the nose shape was lengthened to 16m, and 3-dimensional CFD analysis was used to optimize the front car and reduce the cross sectional area of the train car (fig 7).

5.5 Increase in comfort

In order to greatly reduce horizontal and vertical vibration while running at high speed, progress in the development of the bogie for the next generation high speed Shinkansen has been made and the Fastech 360S has been equipped with 3 types of bogies. The most superior bogie will be selected as the standard bogie based on comfort and through through long-term endurance testing.

Furthermore, an actuator is placed between the bogie and train car body, and an active anti-vibration device (active suspension) is used to control swaying of the body and improve riding comfort. An air type has already been implemented on the E2 series Shinkansen. However, in order to further improve riding comfort, an active suspension system with an electromagnetic actuator that has a large amount of thrust and good response has been installed.

When a curve is passed through at high speed, a large centrifugal force is applied to passengers inside the train lowering riding comfort. A tilt control system is a device used to lean the train car into the curve that counteracts a portion of the centrifugal force and improves riding comfort. The Fastech 360 is equipped with an “air spring stroke type” that delivers air to the air springs on the outside of the bogie through computer control, and based on the radius of the curve and the speed of the train, leans the car towards the inside of the curve.

Minimizing noise inside the train car while running at high speed is important for the contentment of the passengers. This requires a large improvement in the noise isolation capability of the train cars. Here, the Fastech 360 uses a new train car body for the next generation Shinkansen, in which a “floating floor structure” elastically supports the entire customer area floor, a “high-performance noise insulating multilayer window glass” that increases the layer of air, and a new internal trim panel structure etc. have been introduced, and significant improvements have been made to conventional Shinkansen car bodies to create the new car for the next generation of Shinkansen.

6 Conclusion

High speed testing for the Fastech 360S started at the end of June 2005, and the tests are moving forward very well to date. Recently an increased speed test at 400 km/h was implemented and confirmed the train car has stable running performance at high speed. Furthermore, it was confirmed that the fundamental functions that make up the train car have sufficient performance.

Through various tests that will be performed over the next two years, various types of new technologies that have been incorporated in the next generation Shinkansen will have detailed performance confirmation tests under 360 km/h conditions and necessary revisions will be made. Furthermore, the Fastech 360Z type for the direct service between conventional and Shinkansen tracks is scheduled to be completed this spring. Fastech S and Fastech Z are scheduled to undergo coupled tests and pass-by tests in the 2006 financial year.

In parallel with the tests, detailed specifications future Shinkansen car for business based on the Fastech 360 Shinkansen are being planned. This will target completion of a next generation Shinkansen with increased speed and further evolution in terms of safety, compatibility with the environment, and comfort.