Overview of Research and Development for Shinkansen Speed Increases

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JR East launched the Shinkansen High-speed Project in April 2002, carrying out research and development for faster Shinkansen trains under the themes of improvement of running speed, ensuring safety and reliability, improvement of passenger comfort and consideration for the environment, with a goal of a top operation speed of 360 km/h. We have built the Shinkansen high-speed test car sets FASTECH360S (exclusive for Shinkansen) and FASTECH360Z (for through service on Shinkansen and conventional lines) and also improved wayside equipment to implement comprehensive verification of rolling stock and wayside equipment under actual load in the actual operating environment. High-speed running tests were conducted from June 2005 to June 2009, mainly in the section between Sendai and Kitakami on the Tohoku Shinkansen line. Disassembly studies were also conducted to the end of FY* 2009, and we are currently applying the results of those in next-generation of pre-mass production Shinkansen rolling stock.

Tests and studies for the FASTECH360 have all been completed, and a certain amount of results has been achieved. This issue of JR EAST Technical Review is thus a special edition focusing on the start of the Shinkansen High-speed Project, running tests, disassembly studies, and items applied to pre-mass production rolling stock.

Introduction

Shinkansen lines of the JR East network extends from Tokyo in five directions with the Tohoku, Joetsu, Nagano, Yamagata and Akita Shinkansen linking main cities in our operational area. We opened Shin-Aomori station in December 2010 and are planning to open Shin-Hakodate station in FY 2015 on the Tohoku Shinkansen and Toyama and Kanazawa stations on the Hokuriku Shinkansen in FY 2014, steadily making preparations for further expansion of the network. In Europe, meanwhile, a high-speed rail line that opened in Germany (Cologne - Frankfurt) in August 2002 runs at a top speed of 300 km/h and the TGV Est European that opened in France (Paris - Strasbourg) in June 2007 runs at a top speed of 320 km/h. With those and other high-speed lines in operation, it is safe to say that world’s high-speed railways have entered in the area of over 300 km/h operation.

Under these circumstances, we are aiming at improvement of service in the expanded Shinkansen network, improvement of competitiveness with airlines and the top level of high-speed technology in the world. To achieve that, we are carrying out research and development for faster Shinkansen trains centering mainly on improvement of running speed, ensuring safety and reliability, improvement of passenger comfort and consideration for the environment, with a target of a top operation speed of 360 km/h. Up to this point, we have built FASTECH360 Shinkansen high-speed test trains and improved wayside equipment to implement comprehensive verification of rolling stock and wayside equipment under actual load in the actual environment. Technical issues have been overcome for an operation speed of 320 km/h, and pre-mass production rolling stock has been designed and manufactured for the new series E5 high-speed Shinkansen rolling stock. Now, pre-mass production rolling stock is being designed and manufactured.
for the new series E6 Shinkansen/conventional line through service high-speed rolling stock for 320 km/h operation. The Research and Development Center of JR East Group is also working to achieve technical development for 360 km/h operation.

We launched the Shinkansen High-speed Project in April 2002 for increasing the speed of the Shinkansen. The project started by organizing knowledge and identifying issues for reaching targets. It was based on results of internal and external R&D such as that using STAR 21 (test train that achieved a top speed of 425 km/h in test runs from 1992 to 1997) and various data from current train operation.

Such work is very important in terms of preventing duplication and overlooking of issues in research and development. Also, engineers in fields such as rolling stock as well as tracks, power, signals, and civil engineering must all be of the same thinking and efficiently conduct development in as short period of time for high-speed railways that span various technical fields. In the end, just over 70 issues were set and development schedules made for those. Fig. 4 shows the selected issues for speed increase. Computer simulations, device and component prototype production and testing, performance tests for bogies and main circuits on the bogie testing machine at the R&D Center, performance tests using the rolling stock test stand and large wind tunnel at the Railway Technical Research Institute (RTRI), aerodynamic noise tests, and more were conducted according to the details of the issues in elemental development for the set issues. Also, high-speed running tests and the like were conducted in 2003 with series E2-1000 and E3 rolling stock to acquire as much on-track test data of actual trains as possible and to verify elemental development at that point.

The results of those were consolidated by autumn of 2003, and studies of those conducted. The following conclusions were gained.

- While issues related to the environment, ride comfort, and quietness on train still need to be overcome, a certain amount of technical abilities has been amassed for 360 km/h level high-speed operation.
- To gain a more accurate high-level technical outlook for high-speed operation, trains exclusively for high-speed tests need to be made and running tests to be conducted to implement comprehensive evaluation and verification for various items under actual load in the actual operating environment.

The structure of this project is one where promotion of foundational R&D was planned in the early stages. Later, with the start of high-speed running tests using series E2-1000 and E3 rolling stock and FASTECH360, a role of thoroughly promoting those running tests was added. When a certain amount of results from running tests with high-speed test trains was accumulated (at the shift from the R&D stage to the stage where speed increase measures are studied), the structure no longer fit the actual situation. Some subcommittees and working groups were thus restructured and their roles reevaluated.

RTRI also participates in this project in addition to JR East personnel, giving overall instruction on technical development for increasing Shinkansen speed. That institute has amassed technical abilities in specialized fields related to Shinkansen speed increase, and it is important to work closely with that to make R&D proceed efficiently. A study group on R&D for speed increase was thus set.
up and studies were made in overall R&D for Shinkansen speed increases on topics such as exchange of information related to speed increase, sharing R&D issues in speed increase and division of R&D duties between RTRI and JR East. RTRI also studied with JR East on individual technical issues, participating in working groups such as those on the environment, overhead contact lines and pantographs, comfort and adhesion.

Related manufactures were also involved in the development. They participated as contractors for individual development themes.

The FASTECH360 series of test train sets were developed in this project with the concepts of being "a prototype for rolling stock running at 360 km/h", "an experimental platform to clarify phenomena intrinsic to high speed running" and "a stage to offer comfortable moving spaces in near future". It consists of two train sets: the FASTECH360S type E954 Shinkansen high-speed test train exclusive for Shinkansen lines built in June 2005, and the FASTECH360Z type E955 Shinkansen high-speed test train for through service on Shinkansen and conventional lines built in April 2006. In conjunction with the construction of those trains, wayside equipment was improved and high-speed running tests were implemented for comprehensive verification of rolling stock, and wayside equipment under actual load in the actual operating environment starting in June 2005.

### 3.1 FASTECH360S

The FASTECH360S is an eight-car test train set exclusively for the Shinkansen. The 6M2T train set consists of eight cars; trailers with a cab at both ends and six motor cars in between. The trailers have a long nose 16 m in length to control tunnel micro-pressure waves, and the shapes of the noses of the trailers at each end are different to each other to compare the wave control performance. Other visual characteristics include equipment for increasing air resistance, a smooth total diaphragm between cars, noise absorbing panels under cars and cantilever single arm pantographs.

The main circuit consists of three units, one unit per two cars. Those units have different systems from each other for comparison purposes.

To improve ride comfort in curves, the train is equipped with an air spring stroke type of car body tilting system with a maximum incline angle of two degrees.

### 3.2 FASTECH360Z

The FASTECH360Z is a six-car test train set for through service on Shinkansen and conventional lines. The bogies at the ends of both of the trailers are non-motored trailing bogies, and the rest of the bogies of the train set (including those of the trailers at the ends opposite the cabs) are motored bogies. That makes the MT ratio of the train set as a whole equivalent to 5M1T. The main equipment for high speed running and environmental measures of the FASTECH360Z is common with that of the FASTECH360S, except for having a smaller car body and equipment for through service on Shinkansen and conventional lines.

In order to achieve fast running performance on Shinkansen lines and curve performance on small-radius curves on conventional lines, bogies of series E3 cars currently in operation have a 2,250 mm bogie wheelbase. But the FASTECH360Z that aims at speed increase on Shinkansen lines has a 2,500 mm bogie wheelbase, the same as bogies of the test car exclusive for the Shinkansen, emphasizing stability in fast running. However, FASTECH360Z achieves a smaller damping force with switchable yaw dampers of the bogie in running on conventional lines to reduce the lateral force at small-radius curves.
Running performance evaluation, environmental assessment, passing tests, coupling tests and durability assessment tests were conducted in sections such as between Morioka and Hachinohe with the FASTECH360S and between Morioka and Akita (Akita Shinkansen) with the FASTECH360Z. That is in addition to high-speed running tests conducted mainly in the section between Sendai and Kitakami on the Tohoku Shinkansen line. Long-term durability running tests (approx. 600,000 km running) that were an objective from the start were completed in May 2009. Finally, brake performance tests for speed increase to 260 km/h in the downward gradient section between Karuizawa and Takasaki on the Hokuriku Shinkansen (210 km/h restricted section) were added, completing running tests with FASTECH360.

Disassembly studies were conducted after completing running tests to apply results to future Shinkansen design and development. That consisted of evaluation of deterioration in high-speed running and evaluation of devices and components built with new technologies. Studies were conducted on the FASTECH360S from August 2009 to March 2010 and on the FASTECH360Z in 2008.

At the end of 2007, we announced that we plan to gradually increase speeds on the Tohoku Shinkansen from FY 2010, achieving an operation speed of 320 km/h at the end of FY 2012. That announcement was made from a decision that 320 km/h would be appropriate as a speed increase for the time being taking into consideration environmental measures required and cost effectiveness of speed increase found from results of FASTECH360 tests. In line with that decision, pre-mass production rolling stock for the new model Shinkansen rolling stock (series E5) was designed and manufactured at 320 km/h rolling stock performance. Performance tests and durability tests for the series E5 started in FY 2009, and operation started in spring of 2011. Results from FASTECH360 are also applied in the pre-mass production rolling stock for the new model Shinkansen rolling stock (series E6) inaugurated in July 2010, and operation is scheduled to start at a top speed of 320 km/h at the end of FY 2013.

While we have not achieved our goal in Shinkansen speed increase of a top speed of 360 km/h, we will continue to strive in research and development for the next speed increase. We have narrowed down for the most part issues in aiming for the 360 km/h range through FASTECH360 R&D, but it is clear that the remaining hurdles are high. While those will not be solved overnight, we will aim for the next leap forward. This means deepening basic research in identifying phenomena related to reducing noise along lines, dealing with tunnel micro-pressure waves, improving ride comfort in places like curves, and the like based on experience in the current round of speed increases. We will also approach those again from a new point of view, and continue with efforts in research for reducing cost for wayside measures.