Opening of Tohoku Shinkansen Extension to Shin Aomori and Development of New Faster Carriages—Overview of Series E5/E6

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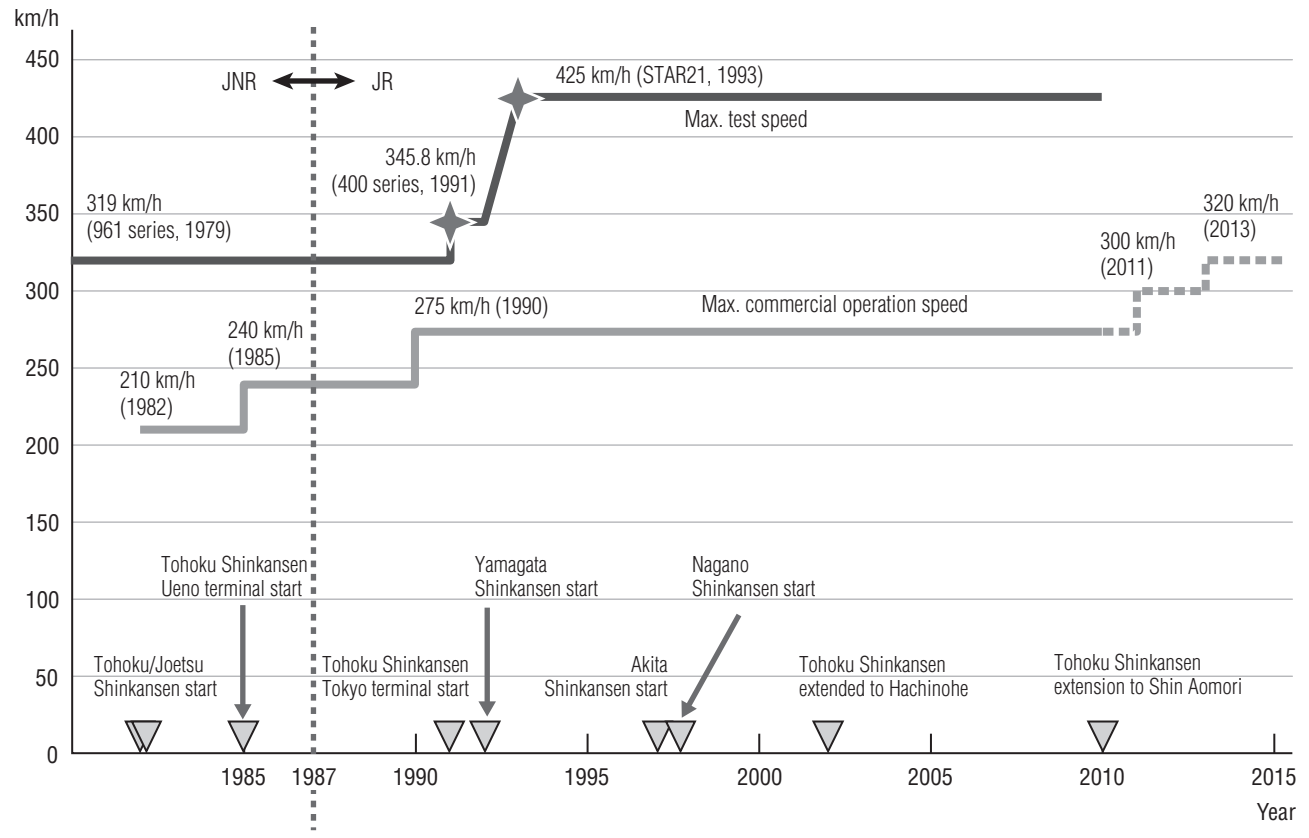
Introduction

In preparation for the December 2010 opening of the Tohoku Shinkansen extension to Shin Aomori, JR East worked steadily from 2002 on technologies to increase speed, finally settling on a commercial operating speed of 320 km/h after various considerations, including running tests using the FASTECH 360 test train. Furthermore, Series E5 pre-production models were built to determine the specifications of carriages used for commercial operations; running tests confirmed the final specifications ahead of introduction of the Series E5 in spring 2011. Moreover, Series E6 pre-production models reflecting development successes using the FASTECH 360 Z were started in June 2010. These carriages will be coupled with Series E5 carriages in commercial operation to run at 320 km/h.

Path to Speed Increase

The Tohoku Shinkansen started operation in 1982 at a maximum speed of 210 km/h. Today, the commercial operation speed is 275 km/h but 20 years have passed since the first 275 km/h operation with Series 200 carriages on the Joetsu Shinkansen in 1990. Full-scale operation at 275 km/h started with the introduction of the E3 and E2 at the opening of the Akita Shinkansen and Nagano Shinkansen in 1997.

Figure 1 Path to Speed Increase



In the following 13 years, various technical developments to increase speed were conducted including FASTECH, leading to 320 km/h operation with the E5 and E6.

Success of FASTECH 360

As its name implies, the FASTECH 360 test train was built to study speed issues with a goal of 360 km/h as the maximum commercial operation speed. Development targets were to increase running speed, assure safety, satisfy environment friendliness, and increase comfort. The technology barriers and costs of speed increase were evaluated from 3 years of running tests, and a maximum speed of 320 km/h was found to be best. Although safety and comfort were confirmed at about 400 km/h, this higher speed was not feasible in terms of environmental performance and cost.

Series E5 Pre-Production Models

Specifications for Series E5 pre-production models were decided in July 2007 and their design and manufacture started. The E5 pre-production models are FASTECH 360 S carriages optimized for commercial speeds of 320 km/h. Development elements were narrowed down from test results to increase the options for equipment with proven track records. The cars were inaugurated in June 2009, and running tests were started to determine mass-production specifications.

Running Tests

Most running tests were between Sendai and Kitakami; environmental performance was the focus of evaluations. To secure passenger capacity, the major difference from the FASTECH design was the nose shape, which was shortened to 15 m compared to the 16-m nose of the FASTECH 360 S. The shorter nose shape was optimized by eliminating unnecessary equipment in the hood, securing the same aerodynamic performance as the 16-m nose.

The effects of changes were verified carefully using the same procedures (wind tunnel tests and simulations) as the FASTECH development.

Running tests confirmed that environmental standards such as tunnel boom could be met at 320 km/h. Although there were differences in generation of micro-pressure waves depending on tunnel entrance hood length, levels equivalent

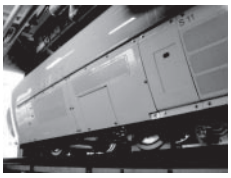
Series E5 *Hayabusa* Pre-Production Model (JR East)

Figure 2 Features of E5 Pre-Production Models

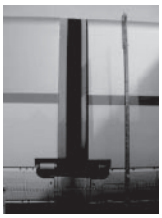
Environment performance improvement

- Long nose to reduce tunnel micro-pressure waves

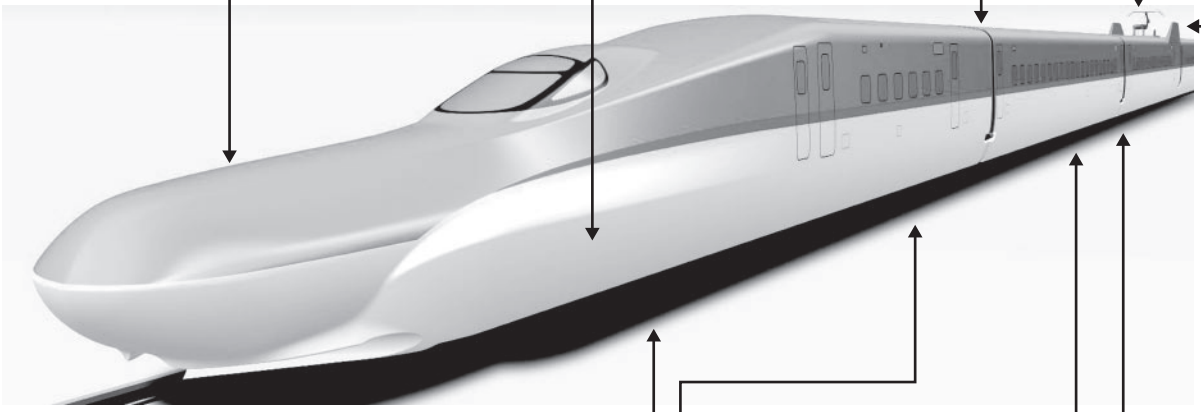
- Bogie cover



- Complete vestibule diaphragm

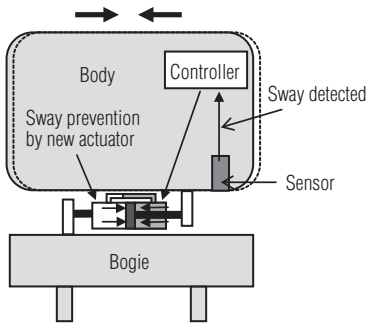


- Low-noise pantograph

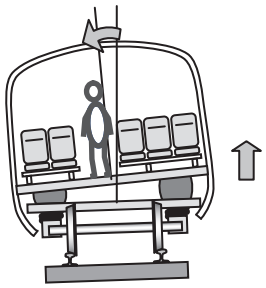


Comfort improvement

- Improved ride comfort from all-car full active suspension (new)



- Improved ride comfort in curves by body tilt control

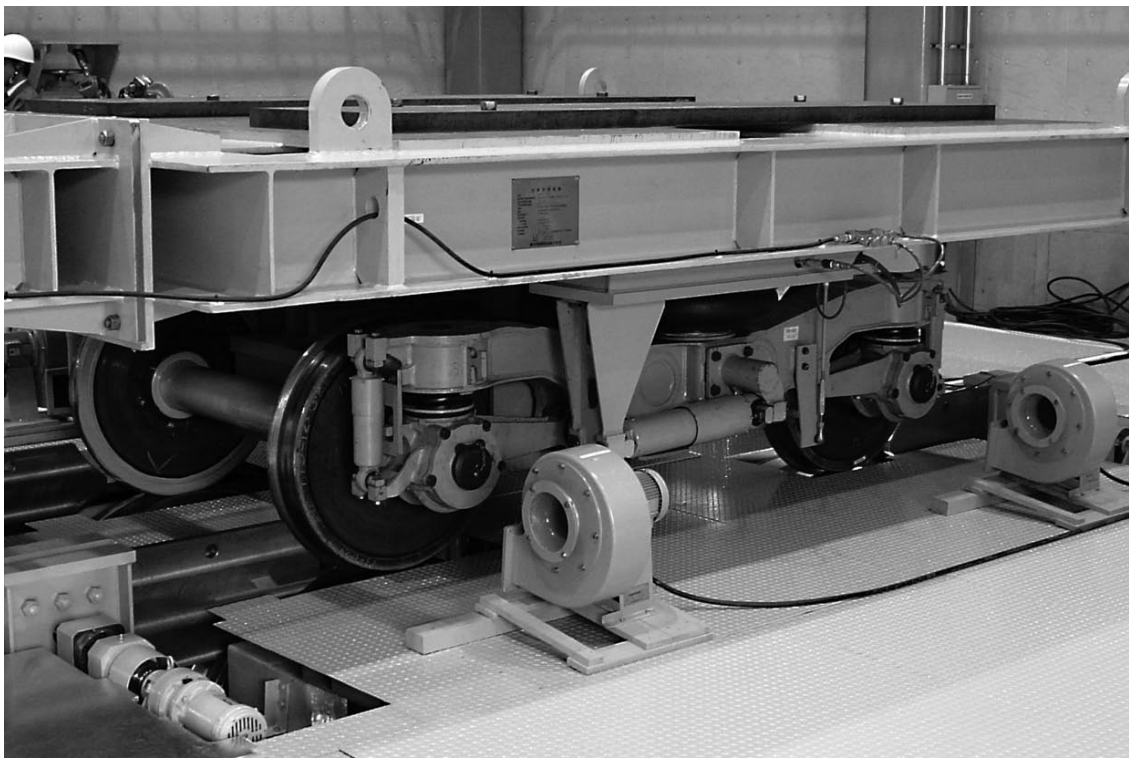


Securing reliability by improved running performance

- Pantograph
- Traction circuit equipment
- Brake equipment

Rolling stock specifications

Pre-production models	
Train set	10 cars (8M2T)
Body	Aluminium alloy body
Max. speed (rolling stock performance)	320 km/h
Control method	VVVF inverter control AC motor



Bogie Endurance Test Rig (JR East)

to FASTECH were confirmed.

To reduce pantograph running noise with the E5, we worked on the premise of using only one < shaped pickup, with the point in the running direction. When the train is run in the opposite direction, the pantograph is switched to another pantograph facing the opposite direction. However, with this design, if a malfunction occurs and a pantograph does not lower, operation would have to be continued with either both pantographs up or with the pantograph facing the opposite running direction. Running tests were conducted assuming such problems to review handling in these abnormal circumstances.

Series E5 Mass-Production Cars

The running tests verified the design performance requirements at 320 km/h and specifications for mass-production were finalized. Test elements for bogie components were also finalized in pre-production models based on performance and maintainability. Although only E5 sets will run at the start of commercial services, their performance at 320 km/h is still sufficient to allow mixed coupling with the E6 now being manufactured.

There are plans to manufacture 59 sets of the E5 including pre-production models to be introduced as replacements for the Series 200 and Series E1, thus increasing speeds.

The basic development premise leading from the FASTECH to the E5 was verification by evaluating actual running conditions to ensure there were no problems in durability or other areas. For bogies where the priority is safety, evaluations were made using bench tests with a 1.2 million km load corresponding to the timing of general inspections. Pantographs and other moving parts were load tested by repeated movement matching the general inspection timing.

Rolling stock was subjected to 600,000-km endurance tests using FASTECH, and then disassembled for detailed inspection and abnormality prediction analysis to confirm that there were no problems. Similar 600,000-km endurance tests over a period of about a 1.5 years are also planned for the pre-production models.

The maximum speed at the end of FY2012 will be 320 km/h or 45 km/h faster than the current maximum commercial speed of 275 km/h. While the speed increase is incremental, it is still a major increase in a short time period. Consequently, it is important to identify the status of rolling stock at maintenance and not to miss even minor abnormalities.

GranClass

Because passengers are demanding even more diverse services, we decided to introduce a *GranClass* to provide higher-grade services than current Green Car first class. This service will be in carriage 10 of E5 trains where 18 customers will be served by special attendants.

Our aim for this new rolling stock is to achieve some

GranClass Interior Image (JR East)

Series E6 Pre-Production Models (JR East)

of the fastest railway speeds in the world, while creating a space that is both healing and relaxing for passengers.

Series E6 Pre-Production Models

JR East Tohoku, Joetsu, Nagano, Yamagata, and Akita shinkansen trains intersect at Omiya, so the schedule is determined by the density of traffic between Tokyo and Omiya. As a result, increasing the speed of the Tohoku Shinkansen requires increasing the speed of coupled trains. Consequently, we decided to increase the speed of the Akita Shinkansen which runs long distances from Tokyo and where the effects of speed increases would be clear. To achieve this goal, we developed the E6 as a successor to the E3 *Komachi*. Running tests of FASTECH 360 Z (E955 series) test cars were made repeatedly. These carriages have contradictory requirements for fast speeds on through operations between shinkansen lines and conventional lines plus good performance on curves on conventional lines, so speed increases create new issues. Much time and effort was required in running tests to evaluate reduction of lateral vibration on shinkansen sections and lateral force on conventional lines.

For conventional lines, we took wayside measures such as increasing rail length by welding rails. We will also continue to closely scrutinize carriage maintenance, and

Table 1 Incremental Speed Increase

Period (scheduled)		Dec 2010	End FY 2010	End FY2012	End FY2013
Max speed	Omiya – Utsunomiya (Current: 240)	240	**275**	275	275
	Utsunomiya – Morioka (Current: 275)	275	**300**	**320**	320
Fastest travel time (Tokyo – Shin Aomori)		3 h 20 min	3 h 10 min	3 h 5 min	
High-Speed Trains		—	*Hayabusa*: 300	• *Hayabusa*: 320 • *Hayabusa*/*Komachi* coupled set: 300	*Hayabusa*/new *Komachi* coupled set: 320

wheel management in particular.

External noise countermeasures are more difficult to implement on the E6 than the E5 because pantograph covers for controlling noise cannot be used on conventional lines due to clearance issues. As a result, the maximum commercial operation speed is decided by the performance of the E955 series. Series E6 pre-production sets are 7-cars long while E3 sets are 6-cars long but have the same capacity. The extra car is needed to secure cabin space due to the longer nose of the Series E6 (6 m in E3 compared to 13 m in E6) to reduce micro-pressure waves in tunnels and because all air conditioning equipment is under-floor to reduce external noise. Test elements were about the same as the Series E5 pre-production models.

The E6 is primarily for replacing the E3 *Komachi* and a total of 26 sets are planned, including the advance mass-production cars.

Operation After Start of Service to Shin Aomori

Currently, six E2 sets are being added to handle the extension of the Tohoku Shinkansen to Shin Aomori; three E5 *Hayabusa* sets will be introduced in March 2011. They have started limited operation at 300 km/h, increasing to 320 km/h from spring 2013. Production is progressing on the remaining 20 sets which will be introduced gradually from summer 2011. Mass-production of the Series E6 will start at that time, so for now, E3 cars are being coupled with E5 cars to run at maximum speeds of 275 km/h. As a consequence, the Series E3 is being modified.

The start of E6 services will be around autumn 2012 when coupled operation with the E5 will start. The speed of the Series E6 will also be increased incrementally, starting at 300 km/h for coupled operation, and reaching 320 km/h in spring 2014.

Conclusion

The speed of the Tohoku Shinkansen is being increased beyond 300 km/h after the opening of the extension to Shin Aomori. Concurrently, the Series 200, E1, and other carriages will start to be replaced, moving forward to a new generation of rolling stock.

Although environmental standards have limited the maximum speed to 320 km/h for the time being, long-term development will continue aimed at reaching 360 km/h.

With the opening of the extension to Shin Aomori, JR East has nearly completed its shinkansen network. However, projected lines, such as the Hokuriku Shinkansen to Kanazawa and the Hokkaido Shinkansen to Hakodate are proceeding in tandem with new developments in rolling stock for those lines. ■

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