Japanese Vision on High Speed and the Environment

Noise Control Engineering in the Case of JR East

May 4, 2011

Takao NISHIYAMA
Executive Director
Japan Railways Group   New York Office
New York, USA
Current Shinkansen Network in Japan

Tohoku Shinkansen Extension
December 2010

Shin-Aomori
Hachinohe
Shin-Osaka
Niigata
Kagoshima-Chuo
Hakata
JR West
JR Kyushu
Nagoya
JR Central
JR East
Tokyo
Nagano
Niigata
Shin-Osaka
Nagoya
Tokyo

2011 International Practicum on Implementing High-Speed Rail in the United States
Track 201
Goals

• Travel time between Tokyo and Shin-Aomori (422 miles):
  4 hours $\iff$ less than 3 hours

• Maximum speed:
  172 mph $\iff$ 225 mph

• Noise level:
  same as present
Noise issue

• Exterior noise is one of the largest environmental issues on high speed in Japan because Shinkansen trains run through residential areas under strict regulations.

• Two large issues:
  • Line-side noise
  • Sonic boom at tunnels (tunnel micro-pressure waves)
Shinkansen noise regulations (1975)

<table>
<thead>
<tr>
<th>Area</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Area</td>
<td>70 dB</td>
</tr>
<tr>
<td>Industrial/Commercial Area</td>
<td>75 dB</td>
</tr>
</tbody>
</table>

Note1: To be measured at 1.2m above the ground, 25m apart.
Note2: Indices are the power average of the 10 largest peak noises among 20 successive trains using the time constant SLOW.

Cf. European TSI

<table>
<thead>
<tr>
<th>Speed</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 km/h</td>
<td>87 dB</td>
</tr>
<tr>
<td>300 km/h</td>
<td>91 dB</td>
</tr>
</tbody>
</table>

Note: To be measured at 3.5m above the rail level, 25m apart, by a test train.
Line-side noise

- Rolling noise, aerodynamic noise, equipment noise, structure-borne noise,…

- Aerodynamic noise becomes dominant when the speed increases

- Aerodynamic noise is proportional to the $6^{\text{th}}$ power of the speed
  
  ex. $172 \text{mph} \rightarrow 225 \text{mph} : 5 \text{ time increase } 
  
  $(225/172)^6=5$
Noise sources of high-speed trains

- Aerodynamic noise from upper part of car body
- Pantograph noise
- Aerodynamic noise from train nose
- Structure-borne noise
- Noise from lower part of car body
Identifying noise source

- Higher resolution than the conventional 2-dimensional microphone array
- Able to create noise source maps combined with car photographs

Spiral microphone array for noise measurement

Line sensor camera to take pictures
Each noise component contribution
(Series E2 commercial train)

Overall noise
Aerodynamic noise from train nose
Noise from lower part of cars
Aerodynamic noise from upper part of cars
Pantograph noise
Structure-borne noise

more than 6dB increase = 4 time increase in noise power!

Overall noise level (275km/h)

A-weighted sound pressure level (slow) [dB]

Time [s]

1s

(a) 275km/h (172mph)  
(b) 360km/h (225mph)
FASTECH Project

- R&D project for JR East aiming at increasing the maximum speed to 360km/h (225mph) with high level safety, environmental friendliness and comfort
- Many tests were conducted by test cars FASTECH360 from 2005 to 2009.
- Noise was one of the major issues.
- The result is reflected in the latest commercial train cars.
Test cars FASTECH360

■ FASTECH360S (Type E954)
Runs only on Shinkansen lines

■ FASTECH360Z (Type E955)
Runs both on Shinkansen lines and conventional lines.

Both train sets can be coupled on Shinkansen lines.
Noise reduction: pantograph

Noise source distribution
(Wind tunnel test)

New aerodynamic shape pantographs
Noise reduction: pantograph

Reduce the number of pantographs

→ 1 pantograph per train set

FASTECH360S

FASTECH360Z

Travel direction
Noise reduction: pantograph

Multi-segment contact strips

Enhance contact performance between strips and a contact wire
Noise reduction: pantograph

Noise insulation plate

- **Z-shaped type** (Early type)
- **45-degree type** (Conventional type)
- **30-degree type** (Improved type)
Pantograph noise peak level

![Graph showing pantograph noise peak level against train speed]

- ▲ FASTECH360S (Pantograph lifted with insulation plates)
- △ FASTECH360S (Pantograph folded with insulation plates)
- ★ Series E2 (Pantograph lifted without insulation plates)
Noise reduction: Measures for lower part of car body

Cover with sound-absorbing panels
Noise reduction: Smoothing body surface

- Smoothing the nose
- Bogie cover
- Gap with smooth cover
Noise reduction: measures for infrastructure

- Noise-absorbing panels
- Lower the stiffness of rail pads
- Increase the height of noise barrier
Effect of sound-absorbing panels

A-weighted sound pressure level at 25m [dB(A)]

Train speed [km/h]

- Sound-absorbing
- Not sound-absorbing

1 dB
Each noise component contribution (FASTECH360S)

- Overall noise
- Aerodynamic noise from train nose
- Noise from lower part of cars
- Aerodynamic noise from upper part of cars
- Pantograph noise
- Structure-borne noise

Noise level has been decreased by 5 dB.

(a) E2 360km/h (225mph)  →  (b) FASTECH360S, 360km/h (225mph)
Noise source distribution of FASTECH

(a) At the early stage
(b) After improvement

At approximately 340 km/h (212 mph) without noise barriers
Sonic boom in tunnels
(Tunnel micro-pressure waves)

• High-speed trains radiate sonic boom (tunnel micro-pressure waves) when entering into tunnels.

• This sonic boom is proportional to the 3rd power of the speed.

  ex. 172 mph ⇔ 225 mph : 2.2 times increase
  \((225/172)^3=2.2\)
Minimizing tunnel micro-pressure waves

For ground facilities
- Extension of the pressure buffer
- Larger tunnel cross-sectional area is advantageous

For rolling stock
- Extension of nose length
- Optimization of nose shape
- Reduction of cross-sectional area
Comparison test of nose shape

Stream-line Type A

Arrow-line Type B

Type B showed better performance for several tunnels.
Applications for commercial cars: Series E5

- Low noise pantograph
- Cover for the gap between cars
- Bogie covers and sound-absorbing panels
- Nose shape to reduce micro-pressure waves in tunnels

<table>
<thead>
<tr>
<th>Formation</th>
<th>10 cars (8M2T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Speed</td>
<td>320km/h (200mph)</td>
</tr>
<tr>
<td>Train length</td>
<td>250m (820feet)</td>
</tr>
<tr>
<td>Power system</td>
<td>25kV50Hz VVVF control</td>
</tr>
<tr>
<td>Nose length</td>
<td>15m (49.2feet)</td>
</tr>
</tbody>
</table>
Remarks

• Exterior noise issue is one of the major environmental issues for high speed in Japan.

• Reduction of line-side noise and sonic boom at tunnels (micro-pressure waves) are important.

• Noise issues were researched using the test car FASTECH.

• Effective measures have been applied to the latest high-speed rail cars Series E5.
Thank you very much for your attention