15th December 2011

Railway Technical Research Institute (RTRI)
- High Speed Shinkansen- Bolsterless Bogie, Improving Running Performance and Riding Comfort
- Noise Problem of High-speed Train in Japan : Development of Noise Reduction Technology
- Recent Technologies of Train Control Systems in Japan
- Track Technology for High Speed Line in Japanese Railways
High Speed Shinkansen

Bolsterless Bogie
Improving Running Performance and Riding Comfort

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History of maximum speed of Shinkansen

(1) Maximum revenue service speed
- 1964 ~ 210 km/h Inauguration of Tokaido Shinkansen
  Series 0 “Hikari”
- 1986 ~ 260 km/h Series 0, 100 Tokaido Shinkansen
- 1985 ~ 240 km/h Series 200 Tohoku Shinkansen
(1987 break-up and privatization of Japanese National Railways)
- 1992 ~ 270 km/h Series 300 “Nozomi” Tokaido Shinkansen
- 1997 ~ 300 km/h Series 500 “Nozomi” Sanyo Shinkansen
- 2011 ~ 300 km/h Series 500 “Hayabusa” Tohoku Shinkansen
  (+ 2013 ~ 320 km/h Tohoku Shinkansen)

(2) Maximum test speed
- 1996 ~ 443 km/h Series 300X Tokaido Shinkansen

Shinkansen Trains

Maximum revenue service speed of Shinkansen

- Kyushu Shinkansen 270 km/h
- JR-East
- JR-West
- JR-Central

Map showing the maximum revenue service speed of Shinkansen
- Tokaido Shinkansen
- Tohoku Shinkansen
- Sanyo Shinkansen
- Kyushu Shinkansen
Development of High-Speed Shinkansen Bogies

<table>
<thead>
<tr>
<th></th>
<th>Conventional Shinkansen Bogie for Series 100</th>
<th>Bolsterless Shinkansen Bogie for Series 700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogie weight</td>
<td>9,860 kg</td>
<td>6,600 kg</td>
</tr>
<tr>
<td>Unsprung mass</td>
<td>4,650 kg</td>
<td>3,420 kg</td>
</tr>
</tbody>
</table>

Design Concept for Bolsterless Shinkansen Bogie

1) To attain a good balance between increased high-speed running stability and improved performance in negotiating curves to reduce lateral force.

2) Select optimum lateral and longitudinal stiffness of the axle box suspension between wheelset and bogie frame by newly developed analytical method.

2) Lighten a bogie weight, especially unsprung mass by adopting,
   - Simplified shape (Bolsterless, End-beamless) bogie frame made of high-strength steel sheet 8 mm thick
   - Aluminum alloy gear-case and axle-box
   - Hollow axle and 960 mm diameter wheel
   - Caliper-type brake gear and non-motec brake disc
   - Asynchronous induction motor

2) To improve riding comfort, adopt newly designed primary and secondary suspension

Comparison Conventional and Bolsterless Bogie

Bolsterless Shinkansen Bogie

- Greater stability at high speed
- Higher running performance on curves
- Less vibration and greater ride comfort
- Smaller in size and weight
Semi-active control system
improving riding comfort

Semi-active control system

- Vibration
- Yawing cut by changing damper strength
- Force to reduce yawing

Semi-Active Suspension
- Power sources not required
- Safety against abnormal working
- Simple mechanism
- Lower cost than "active type"
- Practically used system installed in Shinkansen vehicles

Shinkansen car body inclination control system
improving carving performance & riding comfort

- Control data transmitter
- Inclination controller
- Maximum inclination angle
- New ATC: 1°
- IS: 1.5°
- Uplift by air spring
- New digital ATC data
- Running speed
- Car's running location

High-Speed Rolling Stock Test Plant

- Maximum test speed: 500 km/h
Introduction

Network of Shinkansen lines in Japan

Contents
- Introduction
- Environmental quality standards for Shinkansen railway noise
- Survey of Shinkansen railway noise sources
- Countermeasures against noise sources of Shinkansen train
- Conclusion
Environmental quality standards for Shinkansen railway noise
(the Environment Agency 1975)

<table>
<thead>
<tr>
<th>Category of area</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$L_{Pa, A,max}$ 70 dB or less</td>
</tr>
<tr>
<td>II</td>
<td>$L_{Pa, A,max}$ 75 dB or less</td>
</tr>
</tbody>
</table>

Category I: the area for mainly residential use.
Category II: other areas, including commercial and industrial areas, where normal living conditions should be preserved.

Temporary 75dB countermeasures
(the Environment Agency, since 1985)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Period</th>
<th>Target areas for 75 dB countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tokaido and San'yodai Shinkansen lines</td>
</tr>
<tr>
<td>1</td>
<td>1985-1994</td>
<td>Areas with highly dense houses continuously</td>
</tr>
<tr>
<td>2</td>
<td>1992-1996</td>
<td>Areas with dense houses</td>
</tr>
<tr>
<td>3</td>
<td>1998-2002</td>
<td>Areas with nearly dense houses</td>
</tr>
</tbody>
</table>
Temporary 75dB countermeasures and state of Shinkansen noise

After the third temporary 75dB countermeasures, the peak noise level $L_{pA, max}$ is less than 75dB at all measured points in target areas in Tokaido, Sanyo, Tohoku and Joetsu Shinkansen lines.

- Survey of Shinkansen railway noise
Rolling Noise from Wheels and Rail

- Smoothing of wheel tread surface:
  - Grinding of rail
  - Damped wheels
  - Smoothing of rail tread surface

Grinding of rail

SPL at the point 3m from the rail

- Countermeasures against noise sources of Shinkansen train

Measurement of noise source distribution

Acoustic mirror
Noise from Concrete Bridge Structures
Countermeasures by reduction of external forces

- Smoothing of wheel tread surface
- Smoothing of rail tread surface
  Grinding of rail nearly 5dB(A)
- Reduction of train weight

$$\Delta L_n = 20 \log_{10} \left( \frac{W_1}{W_0} \right)$$

$W_1$: Reduced weight, $W_0$: Non-reduced weight

Countermeasures by insulation of vibration

- Ballast mat
- Sleeper covered with resilient materials on ballasted track
- Ballast mat with groove
- Slab with sleeper
- Vibration-reducing track (G-type)
- Sleeper covered with resilient materials fastened to slab track

Aerodynamic noise sources

- Pantograph
- Insulator
- Louver for intake air
A number of countermeasures against Shinkansen noise and bridge structure noise, rolling noise, spark, crack and electrostatic noise have been developed since the Tokaido Shinkansen line was opened in 1964.

At present, the peak noise level can be kept less than 75dB specified in areas of category 1 in all Shinkansen lines.

Successive efforts are needed to achieve 70dB specified in areas of category 1.
Recent Technologies of Train Control Systems in Japan

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Director
Research & Development Promotion Division
Railway Technical Research Institute

Recent technologies of train control systems in Japan

- Safety and Reliability
- System development
- Traffic control
- Interlocking
- Automatic train protection
- Train detection
- Train radio

Safety and Reliability

Safety technologies
- Redundancy
  (2 out of 3 CPUs, dual CPUs)
- Error detection
- Safety-fixed output

High reliability technologies
- Redundancy
  (dual CPUs) × 2, 2 out of 3 (dual CPUs)
**Safety technology**
- dual computer architecture -

**Traffic control systems**
- Integrated traffic control systems has been developed
  - COMTRACK
  - COSMOS
- COSMOS
  - transportation plan, traffic control, facility management, rolling stock management
  - Temporary speed restriction from dispatcher
  - Maintenance procedures are directly carried out between dispatchers and maintenance workers without station staff

**Safety technology**
- analogue input circuit -

**Electronic interlocking**
- More than 1000 electronic interlocking systems are operating on Shinkansen and convention lines
- Improvement of microcomputer's performance
- Various architectures coping with the scale of station are realized
- Improvement of productivity, maintainability and facilitate installation.
  - CAD system generating interlocking table
**Automatic train protection**

- ATC (cab signal, continuous transmission using track circuit)
  - Transmitting: track circuits
  - Signal: speed → distance to go
  - Data transmission: analog → digital
  - Brake control: multi-step → one-step
  - Data and process for train control: wayside → on-board

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**Conventional ATC**

- Service brake is activated automatically
- Released automatically

**Digital ATC**

- Train speed
- ATC emergency braking profile

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**Conventional ATC**

- Wayside
- On-board

**Digital ATC**

- Wayside
- On-board
Train detection

- Track circuits are widely used
  - prevention of shunting malfunction
  - EMC (electromagnetic compatibility)

Train radio

- LCXs (Leaky Coaxial cables), instead of space-wave radio, are used for stable communication
- Digital transmission systems are introduced

  - Specification
    - frequency: 40MHz band
    - service area: more than 99.99%
    - bit error rate: less than 10^{-4}

- Information such as emergency information, character news are transmitted to trains

Conclusion

- Various requirements
  - Train headway, Train speed
  - RAMS
  - Cost
  - Convenience
  - Environment-compatibility

- Technical circumstances
  - Power supply frequencies
  - Radio frequency bands

Progressive information technologies and network technologies should be utilized
2. Track Technology Division

Contents

1. Track technology division of the RTRI
2. The "Slab track" ballastless track
3. Track irregularity index
### Comparison of performance

<table>
<thead>
<tr>
<th>Items</th>
<th>Ballasted</th>
<th>Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction cost</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Construction speed</td>
<td>Even</td>
<td>Even</td>
</tr>
<tr>
<td>Construction precision</td>
<td>Even</td>
<td>Even</td>
</tr>
<tr>
<td>Durability</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Elasticity</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Maintainability</td>
<td>Even</td>
<td>Even</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

### Difference between Mid-chord and Asymmetric-chord Measuring Method

- **Mid-chord Method**
  - Carbody reference = Rigid heavy carbody
  - By 3 bogies
- **Asymmetric Method**
  - Laser reference = Normal carbody
  - Center bogie: Instable at high-speed (~Max. speed 210 km/h)
  - By 3 axles

### 3. Track inspection system

"Doctor Yellow," for the Shinkansen

- Started to use in 1975.
- Maximum speed was 210 km/h.

### 2-bogie Track Inspection Cars

- Same speed as commercial train (270, 275 km/h)
- JR-Central 923 "New Doctor Yellow"
- JR-East E926 "East-i"
  - (For standard gauge lines)
Inertia versine inspection device

Kyushu Shinkansen 800 series

Track irregularity index for Meter gauge

<table>
<thead>
<tr>
<th>Type</th>
<th>Alert Limit</th>
<th>Immediately Action Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>1st Rank</td>
<td>2nd Rank</td>
</tr>
<tr>
<td>Gauge</td>
<td>+10</td>
<td>-5</td>
</tr>
<tr>
<td>Cross level</td>
<td>11 (7)</td>
<td>12 (9)</td>
</tr>
<tr>
<td>Height</td>
<td>13 (7)</td>
<td>14 (9)</td>
</tr>
<tr>
<td>Street</td>
<td>13 (7)</td>
<td>14 (9)</td>
</tr>
<tr>
<td>Twist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) In the inside, it is a unloaded value.

Definition of track irregularity

Track irregularity index for Shinkansen (JR-EAST)

<table>
<thead>
<tr>
<th>Category</th>
<th>Immediately Action Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge</td>
<td>Above 270km/h</td>
</tr>
<tr>
<td>Cross Level</td>
<td>+8</td>
</tr>
<tr>
<td>Height</td>
<td>7</td>
</tr>
<tr>
<td>Alignment</td>
<td>10</td>
</tr>
<tr>
<td>Twist</td>
<td>10</td>
</tr>
</tbody>
</table>
### Track Irregularity Index for Shinkansen (JR-EAST)

**Long Chord Versine (Alert Limit)**

<table>
<thead>
<tr>
<th>Category</th>
<th>20m</th>
<th>40m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal level</td>
<td>8mm</td>
<td>7mm</td>
</tr>
<tr>
<td>Alignment</td>
<td>7mm</td>
<td>5mm</td>
</tr>
</tbody>
</table>

### Track Maintenance Database System “LABOCS”

- **Track Inspection Car**
- **Data Processing**

### EN 13848-5 (Excerpt)

<table>
<thead>
<tr>
<th>Velocity (km/h)</th>
<th>Longitudinal Level</th>
<th>Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V \leq 80 )</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>( 80 &lt; V \leq 120 )</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>( 120 &lt; V \leq 160 )</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>( 160 &lt; V \leq 230 )</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>( 230 &lt; V \leq 300 )</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>

Amplitude of actual track irregularities