RAILWAY OPERATIONS IN SWEDEN AND JAPAN
Similarities and differences with a particular focus on wheel/rail deterioration

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2. Comparison of rail / wheel specification

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4. Comparison of mitigating actions

5. Conclusions

6. Brief introduction of RTRI
<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>9.5</td>
<td>127.6</td>
</tr>
<tr>
<td>(21 persons/km²)</td>
<td></td>
<td>(338 persons/km²)</td>
</tr>
<tr>
<td>Land area (thousand km²)</td>
<td>450</td>
<td>378</td>
</tr>
</tbody>
</table>
General comparison

Total length of tracks

<table>
<thead>
<tr>
<th></th>
<th>Standard (1435mm)</th>
<th>Narrow (1067mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>8 154 km</td>
<td>7 603 km</td>
</tr>
<tr>
<td>Electrified</td>
<td>9 780 km</td>
<td>20 257 km</td>
</tr>
</tbody>
</table>

13 642 km | 28 070 km

www.trafikverket.se
International railway statistics 2008 of UIC
General comparison

Gross hauled tonne-kilometres of trains running on the network 2008

Total : 65 488 (millions tonnes-kilometres) [Sweden]

Total : 285 991 (millions tonnes-kilometres) [Japan]

- Freight: 70%
- Passenger: 30%

- max axle load 30t
- max speed 200 km/h

- Freight: 21%
- Passenger: 79%

- max axle load 18t (conventional)
- max speed 300 km/h

International railway statistics 2008 of the UIC
Punctuality – Sweden

Trains arriving within prescribed “allowed delays”

Percentage of trains operating all of the planned route

http://www.trafikverket.se/Om-Trafikverket/Trafikverket/Manatlig-trafikrapport/Transport-pa-jarnvag-i-ratt-tid/
Punctuality – Sweden

Causes of delays in January and July, 2012

http://www.trafikverket.se/Om-Trafikverket/Trafikverket/Manatlig-trafikrapport/Transport-pa-jarnvag-i-ratt-tid/
General comparison

Punctuality – Japan

Causes of delays in 2009

Total

- Disaster 34%
- Infra 9%
- Train 16%
- External 37%
- Others 4%

Metropolitan area (Tokyo, Chiba, Saitama, Kanagawa)

- Disaster 6%
- Infra 13%
- Train 13%
- External 64%
- Others 4%

- Regulation -

Railway companies have to report to the government if the train is delayed over 30 min..

Turnover 2008

Total 1,728 millions euros
Total 29,658 millions euros

The portion of passenger traffic is quite large in Japan.
The portion of freight traffic in Sweden is large, compared with that of Japan.

International railway statistics 2008 of UIC
### Comparison of rail / wheel specification

<table>
<thead>
<tr>
<th>Europe</th>
<th>Cmax</th>
<th>Si max</th>
<th>Mn max</th>
<th>P max</th>
<th>S max</th>
<th>$\sigma_t$(MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C46GT</td>
<td>0.46</td>
<td>0.38</td>
<td>1.15</td>
<td>0.035</td>
<td>0.035</td>
<td>600-720</td>
</tr>
<tr>
<td>C55GT</td>
<td>0.55</td>
<td>0.38</td>
<td>0.86</td>
<td>0.035</td>
<td>0.035</td>
<td>700-820</td>
</tr>
<tr>
<td>C57GT</td>
<td>0.57</td>
<td>0.38</td>
<td>1.05</td>
<td>0.035</td>
<td>0.035</td>
<td>750-880</td>
</tr>
<tr>
<td>C67GT</td>
<td>0.67</td>
<td>0.38</td>
<td>0.86</td>
<td>0.035</td>
<td>0.035</td>
<td>800-940</td>
</tr>
<tr>
<td>C77GT</td>
<td>0.77</td>
<td>0.38</td>
<td>0.86</td>
<td>0.035</td>
<td>0.035</td>
<td>1050-1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Japan</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P max</th>
<th>S max</th>
<th>$\sigma_t$(MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSW-S</td>
<td>0.60-0.75</td>
<td>0.15-0.35</td>
<td>0.50-0.90</td>
<td>0.045</td>
<td>0.050</td>
<td>730-960</td>
</tr>
<tr>
<td>SSW-Q</td>
<td>0.60-0.75</td>
<td>0.15-0.35</td>
<td>0.50-0.90</td>
<td>0.045</td>
<td>0.050</td>
<td>860-1080</td>
</tr>
</tbody>
</table>

(-S and -Q denote the different thermal treatments), JIS E 5401
# Comparison of rail / wheel specification

<table>
<thead>
<tr>
<th>Type</th>
<th>Solid wheel</th>
<th>Corrugated wheel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image" alt="Solid wheel A" /></td>
<td><img src="image" alt="Corrugated wheel A" /></td>
</tr>
<tr>
<td>B</td>
<td><img src="image" alt="Solid wheel B" /></td>
<td><img src="image" alt="Corrugated wheel B" /></td>
</tr>
<tr>
<td>C</td>
<td><img src="image" alt="Solid wheel C" /></td>
<td><img src="image" alt="Corrugated wheel C" /></td>
</tr>
</tbody>
</table>

- **A type**: High toughness for bogie with motor
- **B type for Shinkansen**
- **C type for Shinkansen**

### Comparison of rail / wheel specification

#### Rail specification

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr max</th>
<th>P max</th>
<th>S max</th>
<th>$\sigma_t$(MPa) min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Europe</strong> SS-EN 13674-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R260</td>
<td>0.62-0.80</td>
<td>0.15-0.58</td>
<td>0.70-1.20</td>
<td>0.15</td>
<td>0.025</td>
<td>0.025</td>
<td>880</td>
</tr>
<tr>
<td>R350HT</td>
<td>0.72-0.80</td>
<td>0.15-0.58</td>
<td>0.70-1.20</td>
<td>0.15</td>
<td>0.020</td>
<td>0.025</td>
<td>1175</td>
</tr>
<tr>
<td>R370CrHT</td>
<td>0.70-0.82</td>
<td>0.40-1.00</td>
<td>0.70-1.20</td>
<td>0.40-0.60</td>
<td>0.020</td>
<td>0.020</td>
<td>1280</td>
</tr>
<tr>
<td>R400HT</td>
<td>0.90-1.05</td>
<td>0.20-0.60</td>
<td>1.00-1.30</td>
<td>0.30</td>
<td>0.020</td>
<td>0.020</td>
<td>1280</td>
</tr>
</tbody>
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<tr>
<td><strong>Japan</strong> JIS E1101 &amp; E1120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As-rolled</td>
<td>0.63-0.75</td>
<td>0.15-0.30</td>
<td>0.70-1.10</td>
<td>-</td>
<td>0.030</td>
<td>0.025</td>
<td>800</td>
</tr>
<tr>
<td>HH340 (Head Hardened)</td>
<td>0.72-0.82</td>
<td>0.10-0.55</td>
<td>0.70-1.10</td>
<td>0.20</td>
<td>0.030</td>
<td>0.020</td>
<td>1080</td>
</tr>
</tbody>
</table>

(As-rolled: 270HV, HH340: 380HV)
Comparison of rail / wheel specification

Swedish rail shape

**50kg**

![Diagram of 50kg rail shape]

**60kg**

![Diagram of 60kg rail shape]

**SS-EN 13674-1**
Comparison of rail / wheel specification

Japanese rail shape

50kgN
(conventional)

60kg
(Shinkansen & conventional with high train density)

JIS E1101 & E1120
Damage situation in Japan

Squats arose at narrow gauge lines in 1950s

- Steam locomotive (large lateral force)
- Water spray to reduce wear in curves
- Heat treated rail
- Modernization of traction: from Steam locomotives to Electric locomotives
- Stop water spray because of improvement of steering performance due to changing steam locomotives to electric locomotives
Appearance of squats (tangent rail)

Single squat

Squats due to WEL

Multiple squats
Comparison of rail / wheel deterioration

Fracture surface of squat

- Dark spot (Squat)
- Origin of crack
- Horizontal crack
- Transverse crack
Comparison of rail / wheel deterioration

Wear & other RCF damage

Head check & Gauge corner crack (squat) (curve rail)

Head check (curve rail)

Head check & Flaking (curve rail)

Corrugation (low rail)
Typical wheel damage of freight wagon

Flat and flange wear were dominant (flat is rare now). Hollow wear and thermal cracks are common (not very detrimental).
Mitigating actions in Japan

Rail
- Preventive grinding (grinding stones)
- Preventive milling (cutting tool)
- Lubrication on low and/or high rails (liquid & solid)
- Better control on running gear and infrastructure and preventive maintenance
- Monitoring of inspection cars (ultrasonic & on-board camera, etc.)
- Material approach (bainitic steel etc.)

Wheel
- Reprofiling (back to original shape)
- Monitoring (camera & sensor mounted in workshop, etc.)
- Flat detection sensor (vibration sensors mounted on the track)
- Better control on running gear (ABS etc.)
- Material approach (modification of wheel shape, corrugated wheel, lubrication on flange and tread, etc.)

.....
Damage situation in Sweden

• Head checks and wheel RCF are dominating
• Sometimes (especially under winter conditions) fast growth of damage

November 22, 2011

• Squats and RCF clusters not very common, but increasing
• Wheel flats and thermal damage fairly common
• Very different damage patterns in different places (diversified operations)

December 19, 2011
Mitigating actions in Sweden

Rail
- Preventive grinding (grinding stones)
- Lubrication mainly liquid on high rails
- Inspection cars (geometry and rail head cracks)
- Head hardened rail in curves
- Profiles
- ...

Wheel
- Reprofiling
- Ultrasonic inspection
- Wheel load and hot wheel / axle box detectors
- Calibration of braking (/ acceleration)
- Wheel profiles
- ...

Comparison of mitigating actions
General damage – wear and plastic deformation

- Distributed wear (hollow wear / flange wear / gauge corner wear)
  - sensitive in destroying contact geometry
  - in severe operations often in combination with plasticity

- Periodic wear (corrugation / out-of-roundness)
  - noise
  - risk of RCF
General damage – RCF

- Distributed RCF defects (head checks and wheel RCF)
  - curving and braking/acceleration
  - typically surface pits on wheels
  - risk of rail breaks

- Single RCF defects (squats and RCF clusters)
  - more random occurrence
  - risk of rail breaks
  - risk of axle box failures
Conclusions

Some concluding remarks

- Japan has about 13 times the population of Sweden. Sweden has about 20% larger area.
- Japan has about twice the railway network size of Sweden with about 4 times the transport volume and 17 times the turnover.
- Japan have higher max speeds, Sweden higher loads.
- In Japan passenger transports dominate, in Sweden freight.
- In simplified terms the main focus in Japan is on punctuality and the main focus in Sweden on costs.
- Material specifications for wheel and rails in Japan and Sweden are comparable.
- Japan uses corrugated wheels and rails with more flat heads, which are not commonly used in Sweden.
- The same types of wheel and rail damage occur in Japan and Sweden, although with different emphasis, e.g.:
  - Japan has experience of squats since the 1950’s
  - Sweden has more “heavy haul related” damage (headchecks and plastic flow/wear on rails, hollow and flange wear, RCF, thermal damage on wheels)
Introduction of RTRI
the rest of time
Almost all the tracks are a standard gauge in Sweden. A lot of narrow gauge lines are in Japan (Shinkansen and conventional lines are completely divided.).

In Sweden, the portion of freight is large. On the other hand, in Japan, the portion of passenger is large.

There are more specifications in Europe than in Japan. Actual specifications of serviced wheels and rails are a little bit different from each other.

Damage situations are common in both even though the focused damage to be solved is different in the case of wheel. (hollow wear, subsurface RCF…. in Sweden, flange wear, thermal cracks …. in Japan)

Practical mitigating actions are similar in both.