Rail Clip Failure Investigation at Sound Transit

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U-Link Extension Opens March 2016

Clip Failures – As of April 11, 2017

<table>
<thead>
<tr>
<th></th>
<th><strong>North Bound Track</strong></th>
<th></th>
<th><strong>South Bound Track</strong></th>
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<tbody>
<tr>
<td></td>
<td>East Rail</td>
<td>West Rail</td>
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<tr>
<td>GUAGE/FIELD</td>
<td>Field Side 4</td>
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<td>Field Side 18</td>
<td>Gage Side 22</td>
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<td>Gage Side 6</td>
<td>Field Side 36</td>
<td>Gage Side 21</td>
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<td>EAST/WEST</td>
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<td>11</td>
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<td>NORTH/SOUTH</td>
<td>20</td>
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<td>97</td>
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<tr>
<td>TOTAL</td>
<td></td>
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Clip Failure
Rail Deflection Measurement
Longitudinal Deflection
Top Plate Vertical Deflection and Rotation
Top Plate Lateral
Southbound Track Rail Rotation

![Graph showing rail rotation over time]

- Y-axis: Rotation - Radians
- X-axis: Time - S
- Two lines indicate E-Rail Rot Field and W-Rail Rot to Field.
Southbound West Rail and Fastener Top Plate Rotation
Longitudinal Deflection
Accelerometers
Acceleration Spectra – Northbound Track

1/3 OCTAVE ACCELERATION - DB RE 1MICRO-G

FREQUENCY - HZ
Acceleration Spectra – Southbound Track

![Graph showing acceleration spectra with different frequency responses for RAIL and CLIP orientations including vertical, longitudinal, and transverse components.]
Broadband Vertical Acceleration
Lab Test - Vertical Accel
Laboratory Test – E-Clip

- Longitudinal Impact
- Lateral Impact
- Vertical Impact

TF - g/LB

FREQUENCY - Hz

856 Hz
1400 Hz
Rail Roughness Prior To Startup

- Roughness in DB RE 1 MICRON vs. Wavenumber in CYC/M
- Comparison of roughness levels for different rail tracks:
  - Southbound track inner rail
  - Southbound track outer rail
  - Northbound track inner rail
  - Northbound track outer rail
- ISO 3095:2005 limit spectrum
Rail Clips
Conclusions

• Center truck produces largest rail rotation and lateral displacement
• No evidence of clip toe load being overcome
• No clear evidence of fatigue due to relative deflection of rail and fastener
• Acceleration spectrum contains strong peaks above 800Hz
• Laboratory tests indicate system resonance at about 800 to 900Hz
• Amplification of rail vibration acceleration at nominally 800 to 900Hz
Outline of ATS Presentation

• Background
• Measurements that were performed
• Analysis
• Conclusions
• Lessons Learned
• Moving Forward
Background...

See Thom’s previous presentation...
Program included:

- Two sites
  - UWS to CHS (subway)
  - SEA to ALS (aerial)
- Visual inspection of the rails
- Rail roughness/corrugation measurements using a Corrugation Analysis Trolley
- Noise measurements on the safety walks
- Onboard noise measurements using the CorrTracker system
Visual Inspection

- UW Station to Capital Hill Station

- Wear band on rail head
- Second wear band on rail shoulder
- Intermittent tail contact with gage face of rail
Visual Inspection

- SeaTac Station to Angle Lake Station

Start of corrugation
Painted rail after one day in service
Raw Rail Roughness, UWS-CHS, 4 runs
## Roughness Wavelengths, Site 1

<table>
<thead>
<tr>
<th>Wavelength, mm</th>
<th>Wavelength, in.</th>
<th>Frequency, Hz @ 55 mph</th>
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<tr>
<td>28.99</td>
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<td>4.94</td>
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</table>
Roughness Spectrogram

1166+50 SB Right Rail (37 mm), Run 20, 1/24 Oct. Bands
Safety Walk Noise and Roughness

Site 1 Close-in Noise Spectrums w Roughness Spectrums at 55 mph

A-Weighted Sound Level, dB re 20 µPa

1/12 Octave Center Frequency, Hz

- NB Average Group A (30-Train Avg)
- NB Left Rail (37mm 4-Run Avg)
- NB Right Rail (34 mm, 4-Run Avg)
- SB Average Group A (47-Train Avg)
- SB Left Rail (37 mm, 2-Run Avg)
- SB Right Rail (37 mm, 4-Run Avg)
- ISO 3095 Spec
Onboard Noise, UWS to CHS
Conclusions

- Rail grinding left ~1.1” wavelength.
- At 55 mph, 1.1” wavelength causes vibration at 848 Hz.
- There are short segments where this wavelength disappears.
- Resonance of rail clips is 800 to 900 Hz.
- Rail clip failures appear to be greater where 800 to 900 Hz peak is stronger.
- Reducing or increasing the grinder speed would change the wavelength and could help resolve problem.
General Observations

• Future measurements should include track time for follow up inspections.
• Onboard measurements can be a valuable tool for identifying problem areas.
• Rail grinding specifications should be updated to address this issue.
• Sound Transit is investigating various approaches.
Acknowledgement

• Shankar Rajaram / Sound Transit
• Xiangdong Han / Sound Transit
• Jason Bailey/ Sound Transit
• Anthony Bohara / HDR
Thank You!

Questions?