Effect of Rail Seat Deterioration on Rail Seat Load Distributions

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Effect of Rail Seat Deterioration on Rail Seat Load Distributions

Outline

• Research Objectives
• Experimentation Overview
  – Wear Depth Profiles
  – Instrumentation Plan
• Rail Seat Load Distribution Data
• Rail Base Displacement Data
• Preliminary Conclusions
• Future Work
Objectives of FRA Task Order 333

• To improve automated inspection of concrete tie rail seat deterioration (RSD)

• To further this objective additional instrumentation and data analysis was provided by UIUC

• Data collected will be incorporated into the project in order to further understand:
  – Rail movement on pre-existing RSD
  – Rail base contact with pre-existing deteriorated rail seats

• This data will augment testing from commercial suppliers of detection services and other research cars
Objectives of UIUC Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

- Compare pressure distribution on rail seats:
  - Under various loading scenarios
  - Under presence of fines
  - Under various stages of rail seat wear
- Develop design metric for mechanistic evaluation of rail seat load distribution
Objectives of RSD Experimentation

• Quantify effect of RSD wear shape and depth on rail seat load distribution

• Correlate rail base rotation to excessive rail seat pressure
  – Encourage mechanistically-defined inspection thresholds to detect unsafe levels of RSD

• Use relationships to guide thresholds for proposed rail seat load distribution design metric
Rail Seat Deterioration Background

- Rail Seat Deterioration (RSD) is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems.
- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked RSD as one of the most critical problems associated with concrete crosstie and fastening system performance.
- Potential RSD mechanisms as determined through research at UIUC:
  - Abrasion
  - Crushing
  - Freeze-thaw
  - Hydraulic pressure cracking
  - Hydro-abrasive erosion
Equipment Preparation and Protection

- Sensors trimmed to fit rail seat
- BoPET and PTFE layered on each side of sensor to protect from shear and puncture damage
- Plastic sleeves and plastic bags to protect sensor tabs and handles from puncture and debris

### MBTSS Setup

- Rail
- Pad/Abrasion Plate
  - BoPET: 0.007”
  - PTFE: 0.006”
  - Sensor: 0.004”
  - PTFE: 0.006”
  - BoPET: 0.007”
- Cast-in Shoulders
- Concrete Crosstie

### Field

Plan View of Sensor and Protective Layers
Field Experiment Program

- **Objective:** Analyze the effect of RSD depth and shape on rail seat load distribution and correlate to rail base rotation

- **Location:** Transportation Technology Center (TTC) in Pueblo, CO
  - **Section 1:** tangent section with 1/4 inch uniform wear
  - **Sections 2 and 3:** curved sections with 1/4, 3/8, and 3/4 inch triangular wear

- **Instrumentation:**
  - MBTSS deployed to capture rail seat pressures and contact area
  - Potentiometers to capture rail base displacement

- **Loading:** FRA T-18 used to apply static and dynamic loads to the track structure
  - Gauge restraint measurement system (GRMS) used to generate varying L/V ratios
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RSD Section Wear Depths

Wear depth (in)

Section 1
Section 2
Section 3

Zone 1
Zone 2A
Zone 2B
Zone 3

Crosstie in Section

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Rail Seat Wear Profiles

Uniform Wear (Zone 1)

Triangular Wear (Zone 2A, 2B, 3)

Zone 1
1/4” Uniform Wear

Zone 2B
1/4” Triangular Wear

Zone 2A
3/8” Triangular Wear

Zone 3
3/4” Triangular Wear

- Smooth, planar rail seat surface
- Field-worn RSD often causes exposed aggregate
  - May generate load concentrations not represented in artificially-worn rail seats
Instrumentation Plan

- Three adjacent ground (high) rail seats instrumented
  - MBTSS used to capture rail seat pressure distribution
  - Potentiometers on rail displacement fixtures used to capture rail base vertical displacement
    - Used to calculate rail base rotation
- No unground (low) rail seats instrumented
Experimental Matrix

• 20,000 lb (88.9 kN) vertical load constant for all tests

• Static tests:
  – L/V force ratios of 0 to 0.8 at 0.2 L/V intervals
  – Load applied at all 3 instrumented rail seats, as well as one rail seat on either side of instrumentation zone

• Dynamic tests:
  – L/V Force ratios of 0, 0.4, and 0.8
  – Conducted at 5 and 15 mph
Effect of Rail Seat Deterioration on Rail Seat Load Distributions

Rail Seat Load Concentration

20,000 lb (88.9 kN) Vertical Wheel Load, 0.6 L/V Force Ratio

- General trend of increasing load concentration toward field side of rail seat with increased wear depth
- Trend of load concentration on right side of rail seat
T-18 Dynamic Run

20,000 lb (88.9 kN) Vertical Wheel Load, 0.8 L/V Force Ratio
3/4” Wear, 15 mph

Field

Gauge

Maximum Pressure (psi)

Time (sec.)

Axle 1
Axle 2
GRMS
Axle 3
Axle 4
Effect of Rail Seat Deterioration on Rail Seat Load Distributions

Effect of L/V Force Ratio on Rail Base Rotation

20,000 lb (88.9 kN) Vertical Wheel Load

L/V Force Ratio

Rail Base Rotation (deg)

1/4" Uniform
1/4" Triangular
3/8" Triangular
3/4" Triangular
Loss of Contact Area

20,000 lb (88.9 kN) Vertical Wheel Load

- No Wear
- 3/8" Triangular
- 1/4" Triangular
- 1/4" Uniform
- 3/4" Triangular
Effect of Wear Depth on Average Pressure

20,000 lb (88.9 kN) Vertical Wheel Load

- 3/4" Triangular
- 1/4" Triangular
- 1/4" Uniform
- No Wear
- 3/8" Triangular
- Uniform Distribution

Average Pressure (psi)

L/V Force Ratio
Effect of Wear Depth on Maximum Pressure

20,000 lb (88.9 kN) Vertical Wheel Load

- 3/4" Triangular
- 1/4" Triangular
- 1/4" Uniform
- No Wear
- 3/8" Triangular
- Uniform Distribution

Maximum Pressure (psi)

Maximum Pressure (MPa)

L/V Force Ratio
Effect of Speed on Contact Area

20,000 lb (88.9 kN) Vertical Wheel Load
Relationship between Rail Cant and Maximum Pressure

20,000 lb (88.9 kN) Vertical Wheel Load

- ▲ 0.8, 15 MPH
- ◇ 0.8, 5 MPH
- ■ 0.8, 0 MPH
- ▲ 0.4, 15 MPH
- ◇ 0.4, 5 MPH
- ■ 0.4, 0 MPH
- ▲ 0.0, 15 MPH
- ◇ 0.0, 5 MPH
- ■ 0.0, 0 MPH

Maximum Pressure (psi) vs. Rail Cant (deg)

Alert: Maximum Pressure (MPa)
- 0.00
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0

Maximum Pressure (MPa)
- 0.00
- 3.45
- 6.89
- 10.34
- 13.79
- 17.24
- 20.68
- 24.13
- 20,000 lb (88.9 kN) Vertical Wheel Load

- Vertical Wheel Load: 20,000 lb (88.9 kN)
Conclusions

• Response of rail base rotation to increased L/V force ratios is consistent
  – Magnitude increases with wear depth
• Contact area is reduced by increasing wear depth
  – 75% reduction with doubling of wear depth
  – Loss of contact area increases pressures
    • 16% increase in average pressure (3/4” triangular wear)
    • 65% increase in maximum pressure (3/4” triangular wear)
• At low speeds, train speed has little effect on loading environment
  – 5% average contact area reduction
• Extreme rail seat pressures may be related to excessive rail cant
  – Increased variability with decreased rail cant
Future Work

- How accurately does artificially-worn RSD replicate field-worn RSD?
- How does the presence of fines or rail seat debris affect RSD failure mechanisms?
- How can these findings be applied to current and proposed industry practice?
  - Can load nonuniformity be correlated to RSD or specific RSD mechanisms?
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