Mechanics of Fastening System Rail Pad Assemblies Through Lateral Load Path Analysis

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Outline

- Background
- Load Path in the Fastening System
- Mechanistic Design Framework
- Research Project Objectives
- Field Setup and Experimental Results
- Conclusions
- Future Work
Background

- 25 million concrete crossties are in use on North American heavy haul freight railroads

- **Industry Trends:**
  - Many variations in fastening system design, performance, and life cycle
  - Fastening system components are failing earlier than their intended design life
  - Increasing heavy axle loads (HAL) and traffic volumes

- **Challenge:**
  - More efficient concrete crosstie and fastening system designs that withstand increasingly demanding loading conditions

Example of Failure Modes in the Fastening System
Defining the Lateral Load Path

- Vertical Wheel Load
- Lateral Wheel Load
- Bearing Forces
- Frictional Forces

Components:
- Rail
- Clip
- Insulator
- Rail Pad Assembly
- Shoulder
- Concrete Crosstie
Mechanistic Design Framework

- Representative input loads and loading distribution factors are not a clear part of the design methodology, particularly in the lateral direction.
- Approach based on loads measured in track structure and properties of materials that will withstand or transfer them.
- Uses responses (e.g. contact pressure, relative displacements) to optimize component geometry and materials requirements.
- Based on measured and predicted response to load inputs that can be supplemented with practical experience.
- Used in other engineering industries (e.g. pavement design, concrete design, structural steel design).
Research Project Objectives

- Increase understanding of vertical and lateral load paths within the track superstructure
- Provide a framework for a mechanistic design approach for concrete crossties and fastening systems
- Quantify displacements of rail pad assemblies relative to crossties in the field and investigate relationship with wheel loads and fastening system lateral stiffness
- Develop recommendations for rail pad assembly design driven by analysis of vertical and lateral load path
Field Experimental Setup

- Objective: Analyze the distribution of forces through the fastening system and impact on components relative displacements
- Tests carried out at TTC in Pueblo, CO
- **High Tonnage Loop (HTL):** 2 degree curve section with Safelok I fasteners
- **Railroad Test Track (RTT):** tangent section with Safelok I fasteners
- Linear potentiometers were used to measure the lateral displacement of the rail base and rail pads
- Strain gauges placed on the rail were used to measure the vertical and lateral wheel loads
- Track Loading Vehicle (TLV) and train consists (passenger and freight) were used to apply loads

![Diagram of Transportation Technology Center (TTC) and High Tonnage Loop (HTL)]
Field Instrumentation

- Potentiometer measuring pad lateral displacement
- Rail Displacement
- Pad Displacement
- LLED

Lateral Load Evaluation Device (LLED) – Williams 2013
Maximum Lateral Wheel Loads and Lateral LLED Forces at Rail Seat U for Increasing Speed
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Fastening System Lateral Stiffness (HTL)

- Rail Seat S: $y = 163514x + 3386.6$
- Rail Seat U: $y = 294810x + 2010.2$

LLED Lateral Force (lbf)

Rail Base Lateral Displacement (in)

- B: rail seat S
- C: rail seat U
- E: rail seat W
- G: rail seat Q

- Rail Seat S: 294,810 lbf/in
- Rail Seat U: 163,514 lbf/in
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Rail Base Lateral Translation for Increasing Wheel Load (HTL Freight Consist)

![Graph showing rail base lateral translation with increasing wheel load. The graph plots rail base lateral displacement (in) against lateral wheel load (Kips). The x-axis represents lateral wheel load in Kips ranging from 7 to 21, and the y-axis represents rail base lateral displacement in inches ranging from 0.006 to 0.022. The graph includes data points for Rail Base S and Rail Base U, with Rail Base S showing a steeper increase in displacement compared to Rail Base U.]
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Rail Pad Lateral Displacement for Increasing Lateral Wheel Load (HTL Freight Consist)

Rail Pad Lateral Displacement (in)

Lateral Wheel Load (Kips)

Rail Pad S

Rail Pad U
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Rail Base and Rail Pad Lateral Displacement for a Varying Lateral Load (RTT)

Displacement (in)

Lateral Force (kips)

40 kips Vertical Load

Rail Base S

Rail Base U

Rail Base E

Rail Base W

Pad S

Pad U

Pad W

Pad E

Rail Base W

Rail Base U

Rail Base E

Pad S

Pad U

Pad W

Pad E
Relative Lateral Displacement Between Rail Base and Rail Pad Assembly (40 kips Vertical Load)
Conclusions

• Relative displacements of the rail pad assembly and rail base with respect to the concrete crosstie were measured successfully in the field.

• The lateral displacement of the rail pad and rail base is directly related to the lateral wheel loads applied to the track.

• Depending on the location of the load application, the lateral displacement of the rail base is able to reach a value 6 times higher than the lateral displacement of the rail pad.

• Rail seats with higher lateral stiffness resulted in a higher percentage of lateral load bearing on the insulator post and shoulder face.

• Adjacent rail seats can have considerable differences in lateral stiffness and resultant magnitude of lateral forces.

• Lateral displacement of rail and rail pad assembly should be considered in fastening system design and material selection.
Future Work: Schnabel
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