Analysis of Rail Pad Assemblies Responses

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Thiago B. do Carmo, Brent Williams, Riley Edwards, Ryan Kernes, Bassem Andrawes, Christopher Barkan
Outline

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• Mechanistic Design Framework
• Research Project Objectives
• Field Setup and Experimental Results
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Analysis of Rail Pad Assemblies Responses

Background

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

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

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

Examples of Failure Modes in the Fastening System Components

_Tearing, crushing, and cracking observed in deteriorated components_
Defining the Load Path

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

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 current design methodology, particularly in the lateral direction.
- Mechanistic design is an 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.
- Can be supplemented with practical experience.
- Used in other engineering applications (e.g. pavement design, concrete design, structural steel design).

Diagram:
- Loads
  - Rail
    - Distribution
      - Fastening System
        - Crosstie
          - Ballast
            - Subgrade
Research Project Objectives

• 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 based on the analysis of vertical and lateral load path
Field Experiment Program

**Objective:** Analyze the distribution of forces through the fastening system and impact on components relative displacements

**Location:** Transportation Technology Center (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

**Instrumentation:**
- 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

**Loading:** Track Loading Vehicle (TLV) and train consists (passenger and freight) were used to apply loads
Field Instrumentation

Potentiometer measuring pad lateral displacement

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

- 315 K Lateral Wheel Load
- Passenger Lateral Wheel Load
- 315 K LLED
- Passenger LLED
Comparison of Fastening System Lateral Stiffness
(Freight Consist on HTL)

- Rail Seat S
- Rail Seat U

Rail Base Lateral Displacement (in)

Rail Seat S:
- 294,810 lbf/in

Rail Seat U:
- 163,514 lbf/in

LLED Lateral Force (lbf)
Analysis of Rail Pad Assemblies Responses

Rail Base Lateral Translation
*(Freight Consist on HTL)*

Rail Base Lateral Displacement (in)

Rail Base S
- B
- C
- E
- G

Rail Base U
- Q
- S
- U
- W

Lateral Wheel Load (Kips)
Analysis of Rail Pad Assemblies Responses

Rail Pad Lateral Displacement
(Freight Consist on HTL)

Rail Pad Lateral Displacement (in)

Lateral Wheel Load (Kips)

<table>
<thead>
<tr>
<th>Rail Pad S</th>
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0.0020 0.0022 0.0024 0.0026 0.0028 0.0030 0.0032 0.0034 0.0036 0.0038 0.0040

7 9 11 13 15 17 19 21
Rail Base and Rail Pad Lateral Displacement
(Track Loading Vehicle on RTT)

Displacement (in)

Lateral Force (kips)

40 kips Vertical Load

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

- **S**
  - Rail Pad
  - Rail Base

- **E**
  - Rail Pad
  - Rail Base

- **U**
  - Rail Pad
  - Rail Base

- **W**
  - Rail Pad
  - Rail Base

Displacement (in)
Conclusions

- Relative displacements of the rail pad assembly and rail base with respect to the concrete crosstie were successfully measured 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 six 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 magnitudes of lateral forces.

- Lateral displacement of rail and rail pad assembly should be considered in fastening system design and material selection.
Future Work: RailTEC’s Research and Innovation Laboratory (RaIL)
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Questions or Comments?

Thiago Bizarria do Carmo
University of Illinois at Urbana-Champaign
Department of Civil and Environmental Engineering
Email: carmo2@illinois.edu

Thank you!