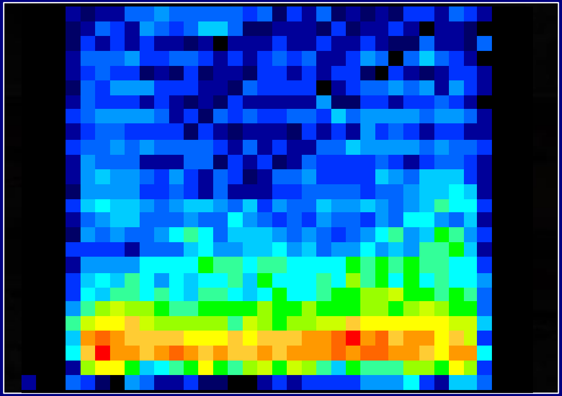
Effect of Elastic Fastener Wear on Rail Seat Load Distributions



Joint Rail Conference

San Jose, CA

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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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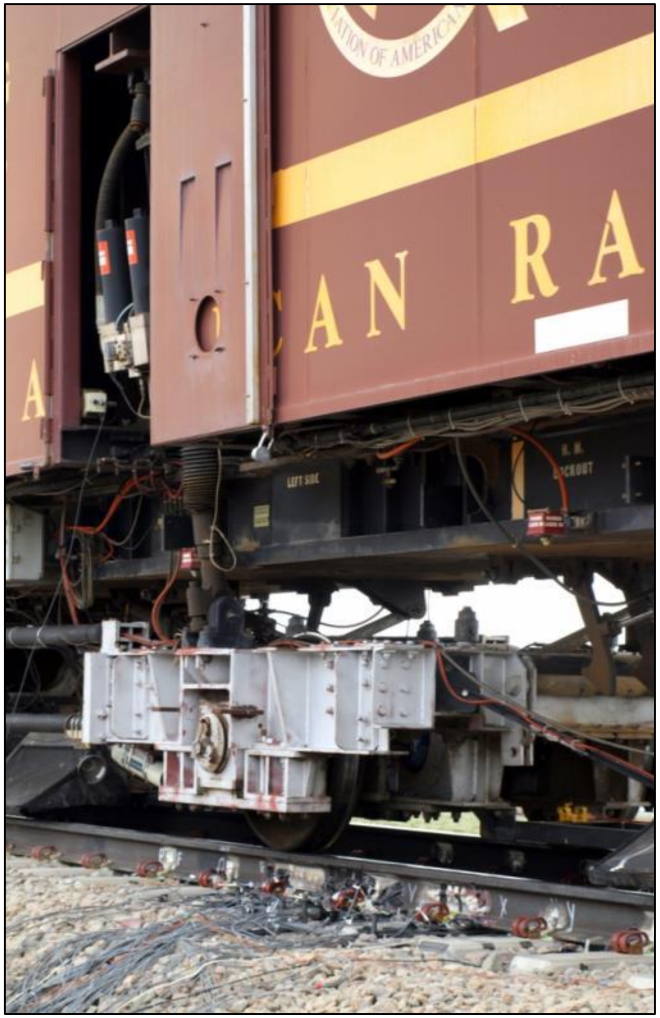
Outline

- Motivation for Research
- Equipment Overview
- Comparison of Current Practice to Lab and Field Results
  - Concentration of Load
  - Quantifying Rail Seat Pressures
- Update on RSLI, a New Design Metric
- Conclusions
- Future Work



Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

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

Motivation for Research

- 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

Gauge

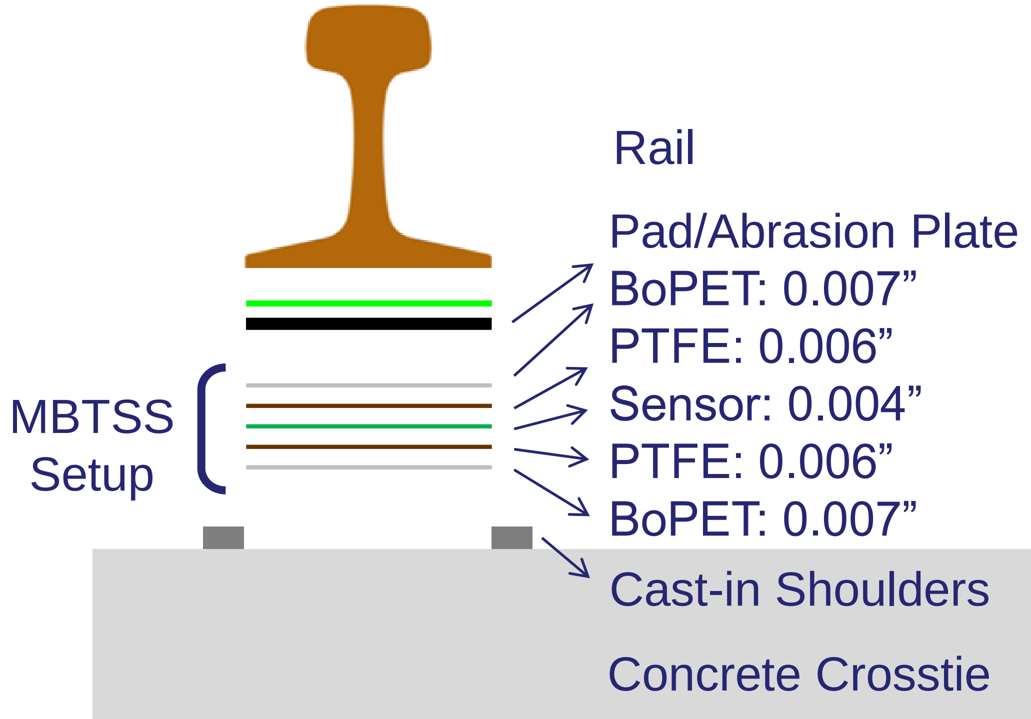
Field

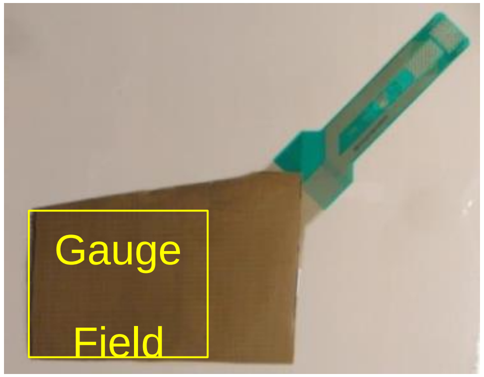
Rail Seat Load Distribution: Current Design Practice

- As of 2014, AREMA Chapter 30 does not contain any design considerations for rail seat load distribution
- Common practice is to assume uniform distribution of rail seat load
- Does not consider:
  - Effect of lateral load
  - Fastening system wear
  - Presence of fines

Equipment Preparation and Protection

- Matrix Based Tactile Surface Sensors (MBTSS) 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



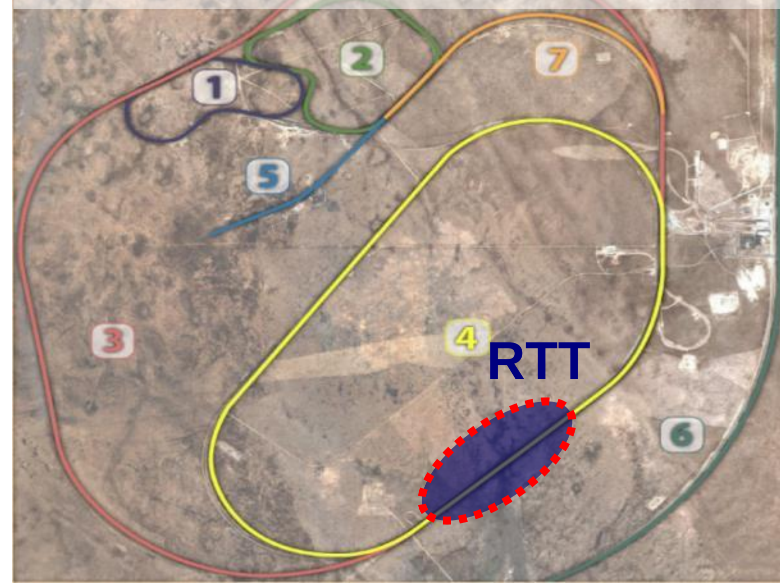


Plan View of Sensor and Protective Layers

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
  - **Railroad Test Track (RTT):** tangent section with Safelok I fasteners
- **Instrumentation:**
  - MBTSS deployed to capture rail seat load concentration, wheel load distribution, behavior of rail seats on the same crosstie, and effect of crosstie support conditions
- **Loading:** Track Loading Vehicle (TLV) used to apply static loads to the track structure
  - Modified railcar with instrumented wheelset on hydraulic actuators

Transportation Technology Center (TTC)



Track Loading Vehicle (TLV)

Laboratory Experiment Program

- **Objective:** Further explore behavior and relationships observed in field experimentation in a controlled laboratory setting.
- **Location:** Research and Innovation Laboratory (RAIL) at Schnabel, UIUC
  - **Track Loading System (TLS):** 22 foot tangent section with Safelok I fastening system and full track substructure
- **Instrumentation:**
  - MBTSS deployed to capture rail seat load concentration, wheel load distribution, and effect of crosstie support conditions
- **Loading:** hydraulic actuators and ram used to apply lateral and vertical loads to track structure through wheelset

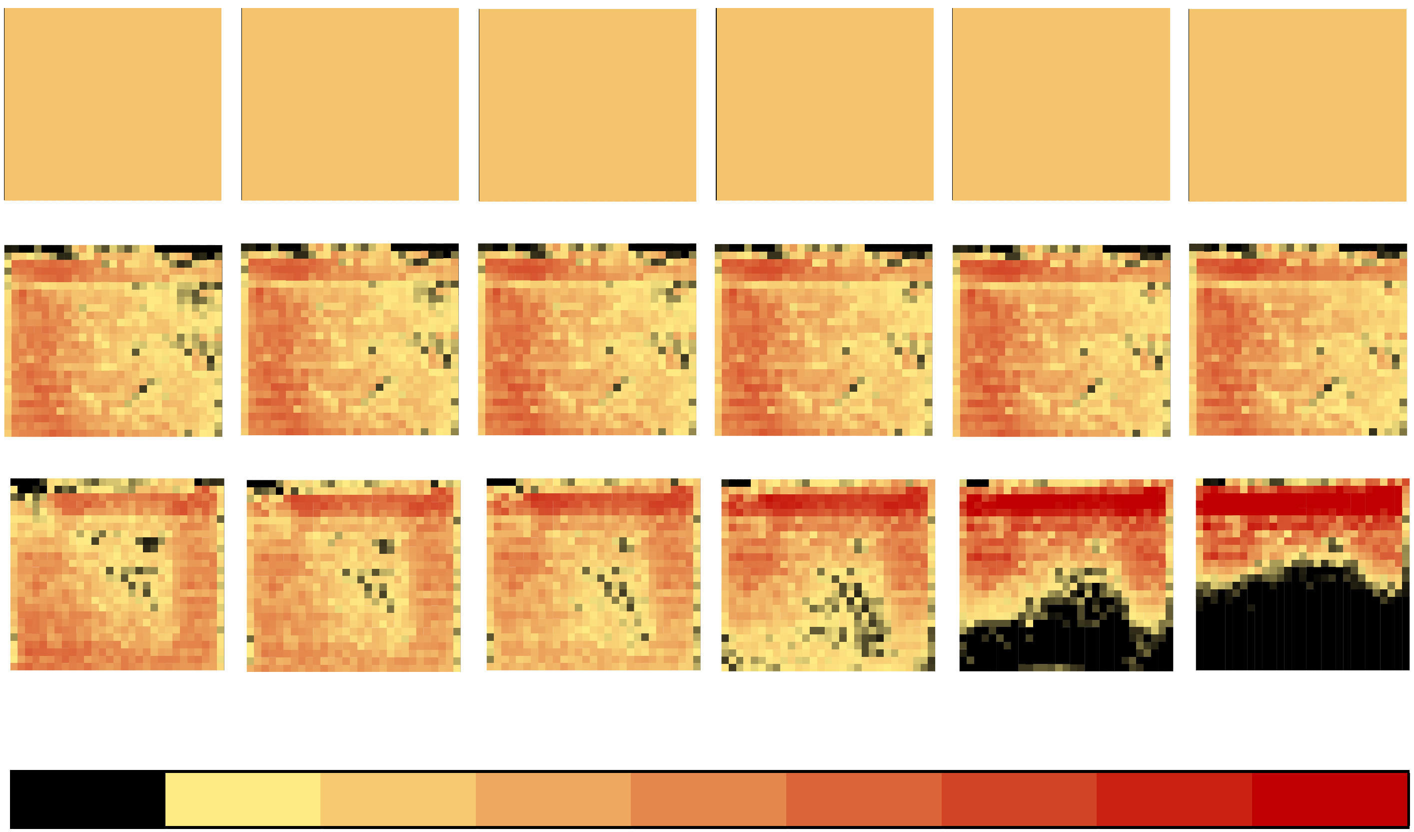
Research and Innovation Laboratory (RAIL)

Track Loading System (TLS)

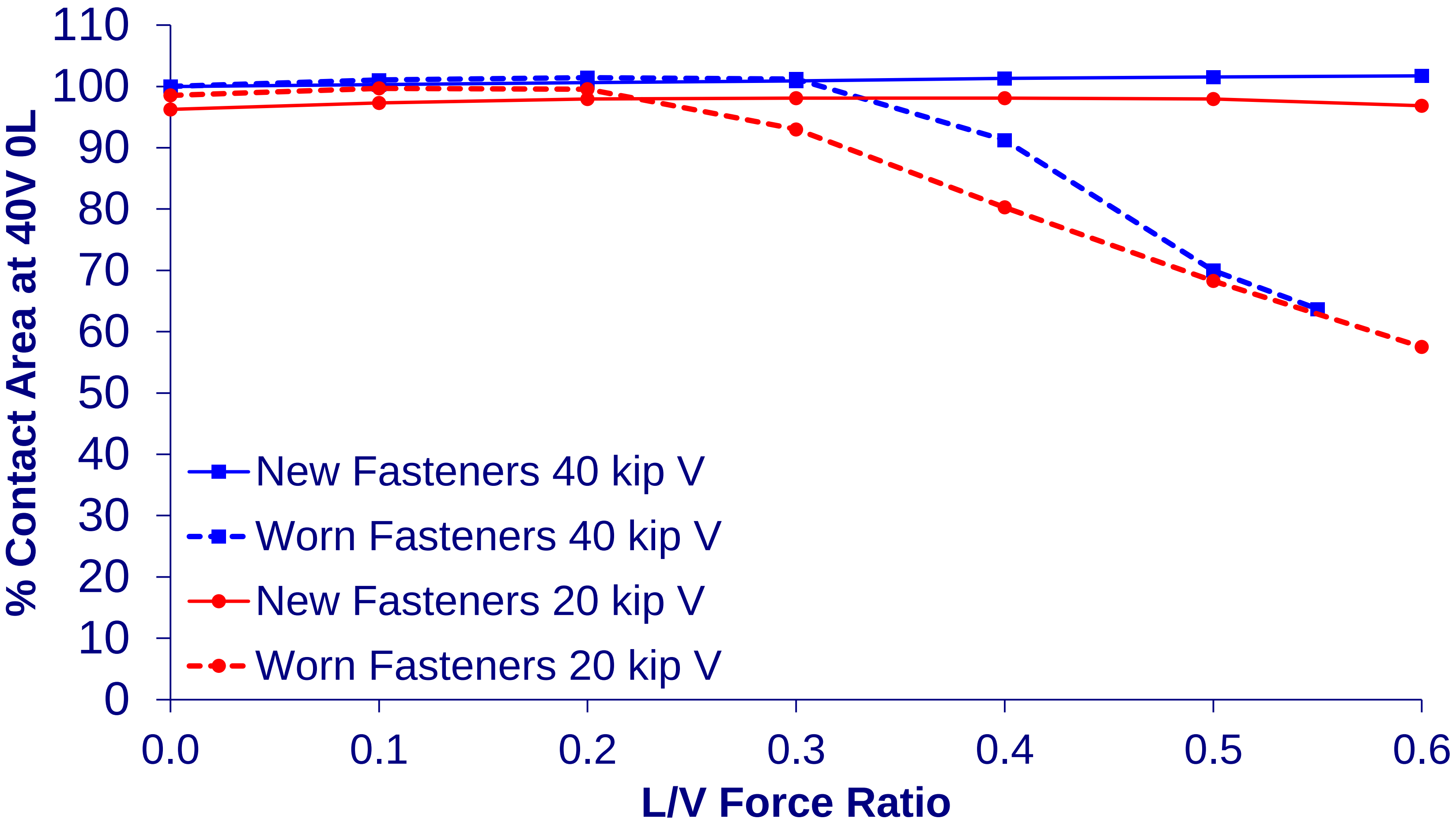
Fastener Condition for Experimentation

- Repeated application of elastic fasteners can lead to a permanent reduction of clamping force at a given deflection
  - In field experimentation, fasteners had experienced 5 MGT of traffic and 3 clip reapplications
  - In laboratory experimentation, all fasteners were applied new
- Fastener wear considered to be largest variable between field and laboratory experimentation

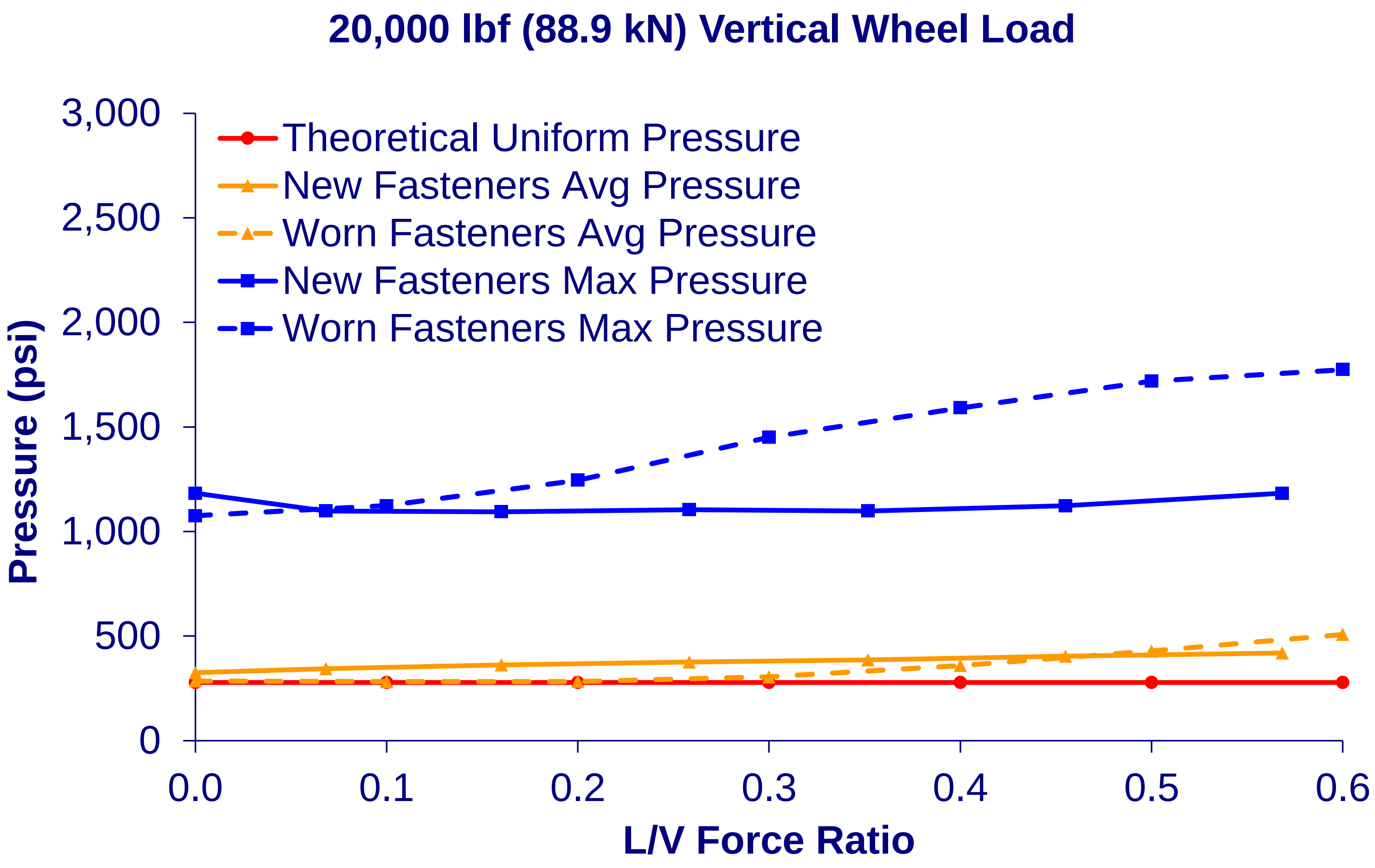
Effect of L/V Force Ratio



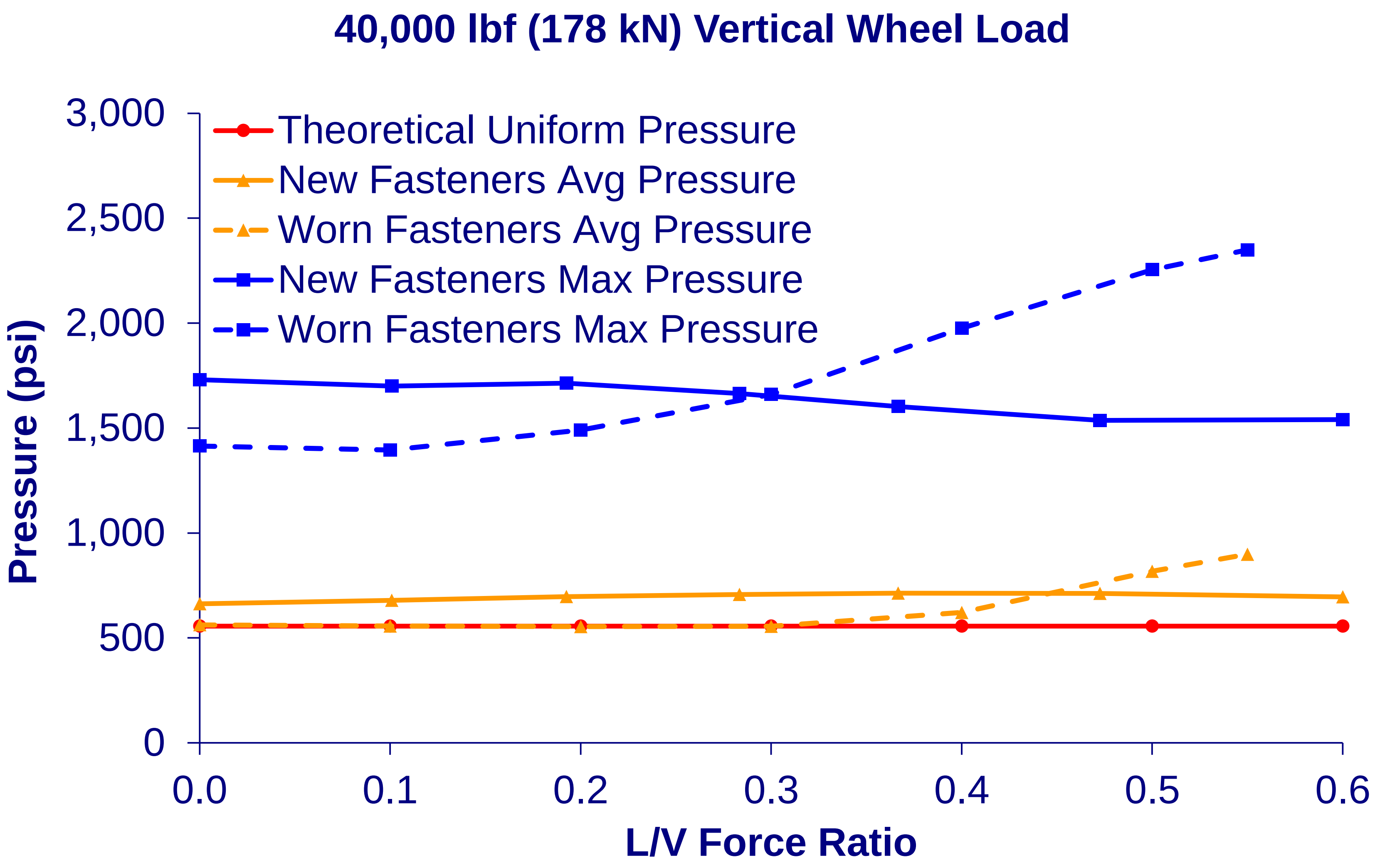
Effect of L/V Force Ratio



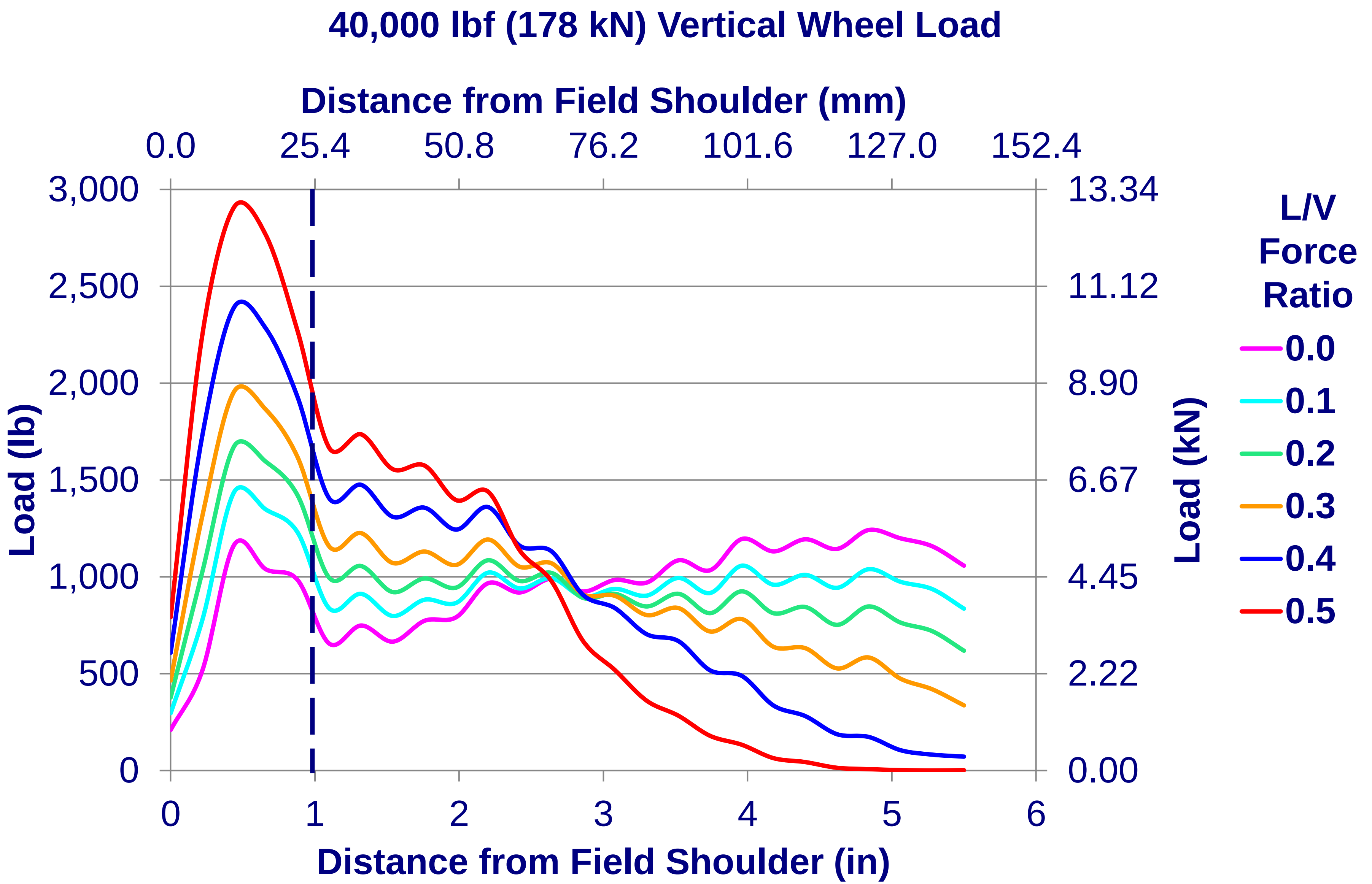
Quantifying Rail Seat Pressure



Quantifying Rail Seat Pressure

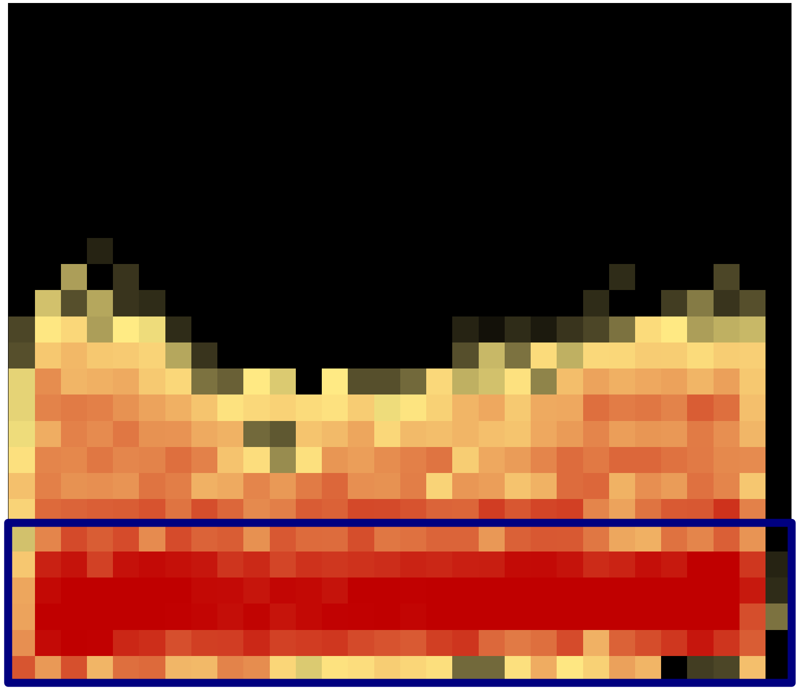


Concentration of Rail Seat Load



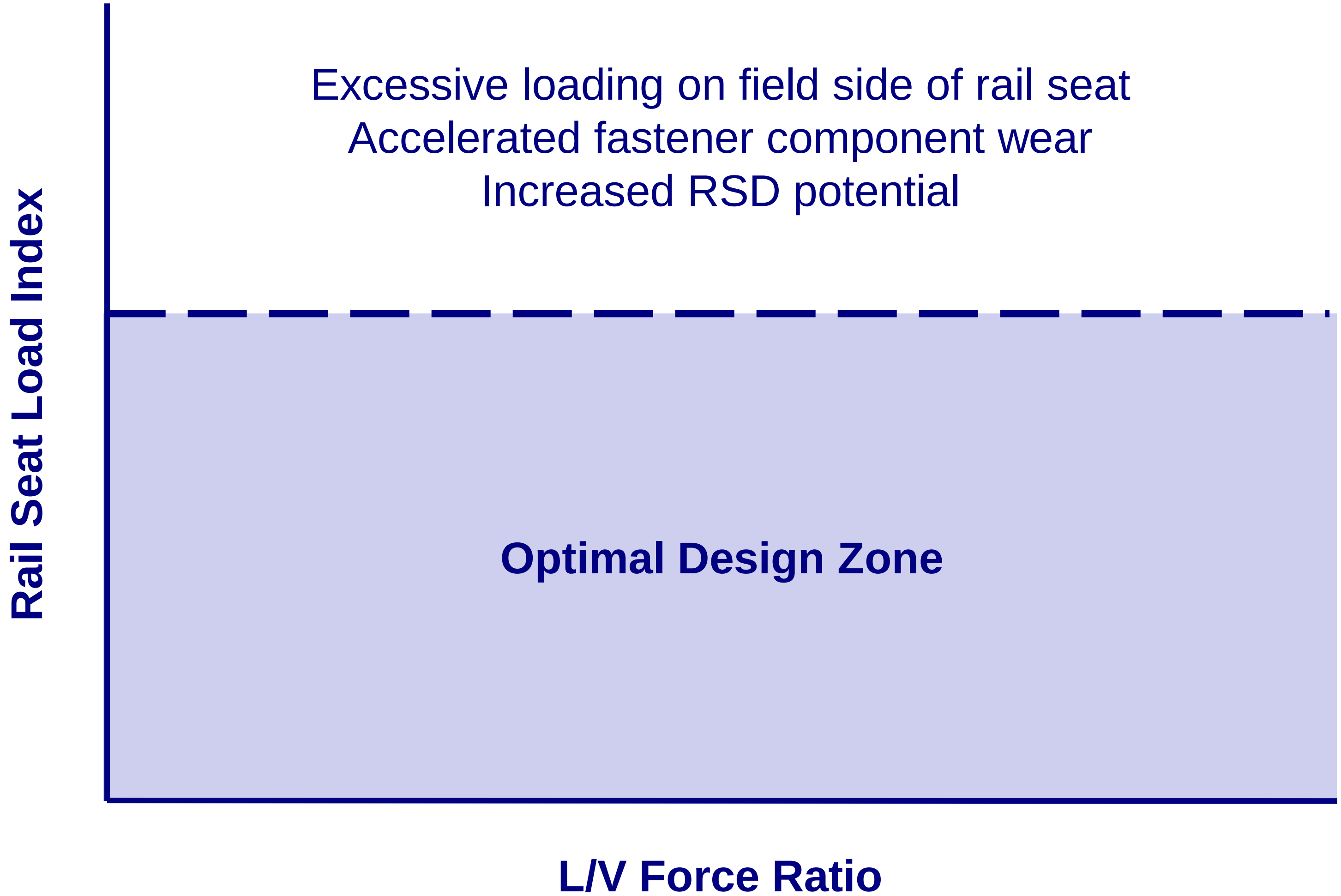
Definition of Rail Seat Load Index (RSLI)

- A quantifiable design value which describes the sensitivity of the rail seat load distribution to changes in the L/V force ratio
- Rail Seat Load Index (RSLI) is defined as the percent of total rail seat load imparted onto a critical region of the rail seat, defined as the area of the rail seat not more than 1 inch (25.4 mm) from the field side shoulder, normalized to a theoretical, uniform distribution.

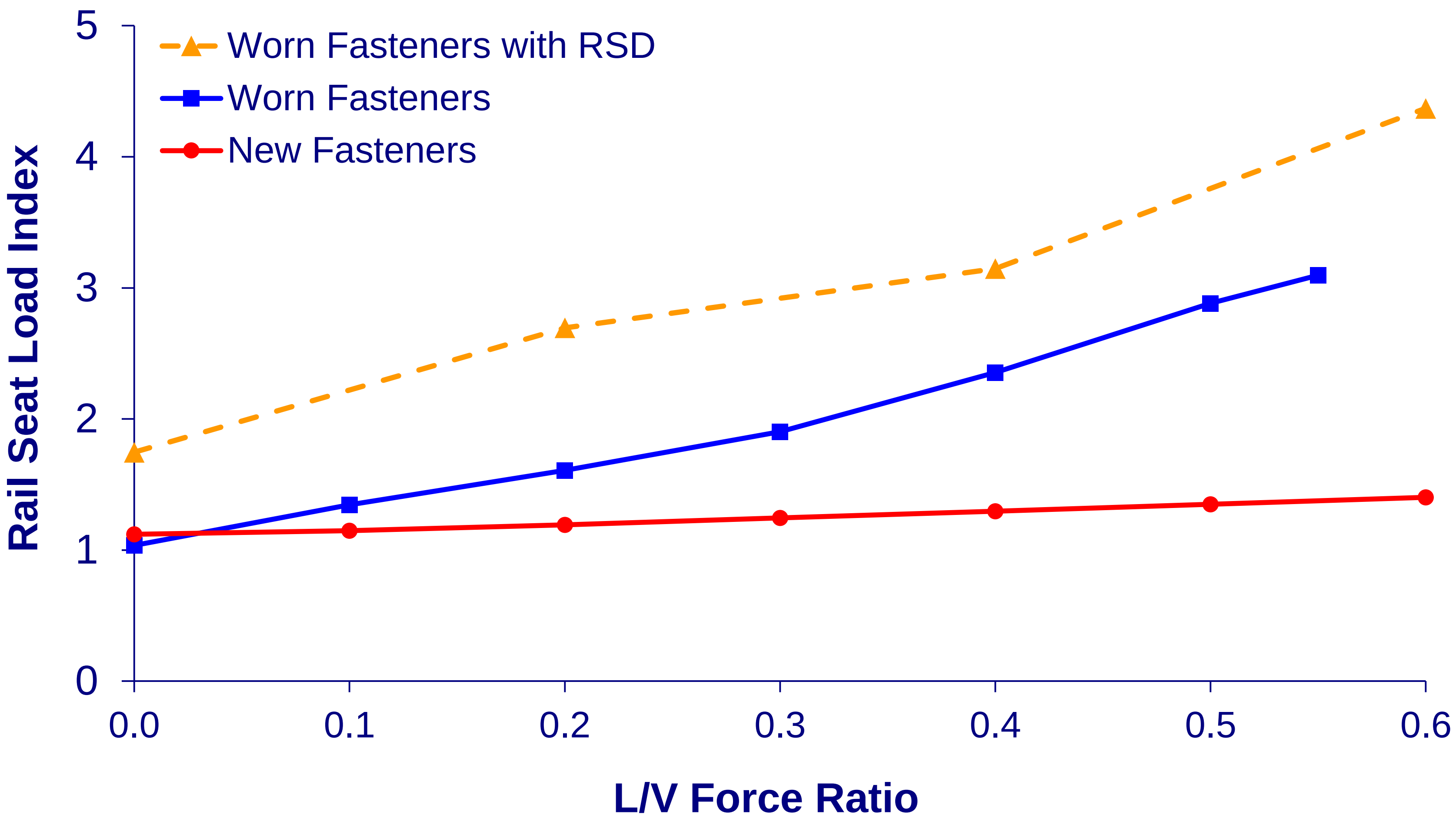


$$RSLI = \frac{\frac{Load\ in\ Critical\ Area}{Total\ Rail\ Seat\ Load}}{\frac{1}{6}} = 6 \times \frac{Load\ in\ Critical\ Area}{Total\ Rail\ Seat\ Load}$$

Theoretical Optimized RSLI



Effect of Fastening System Health

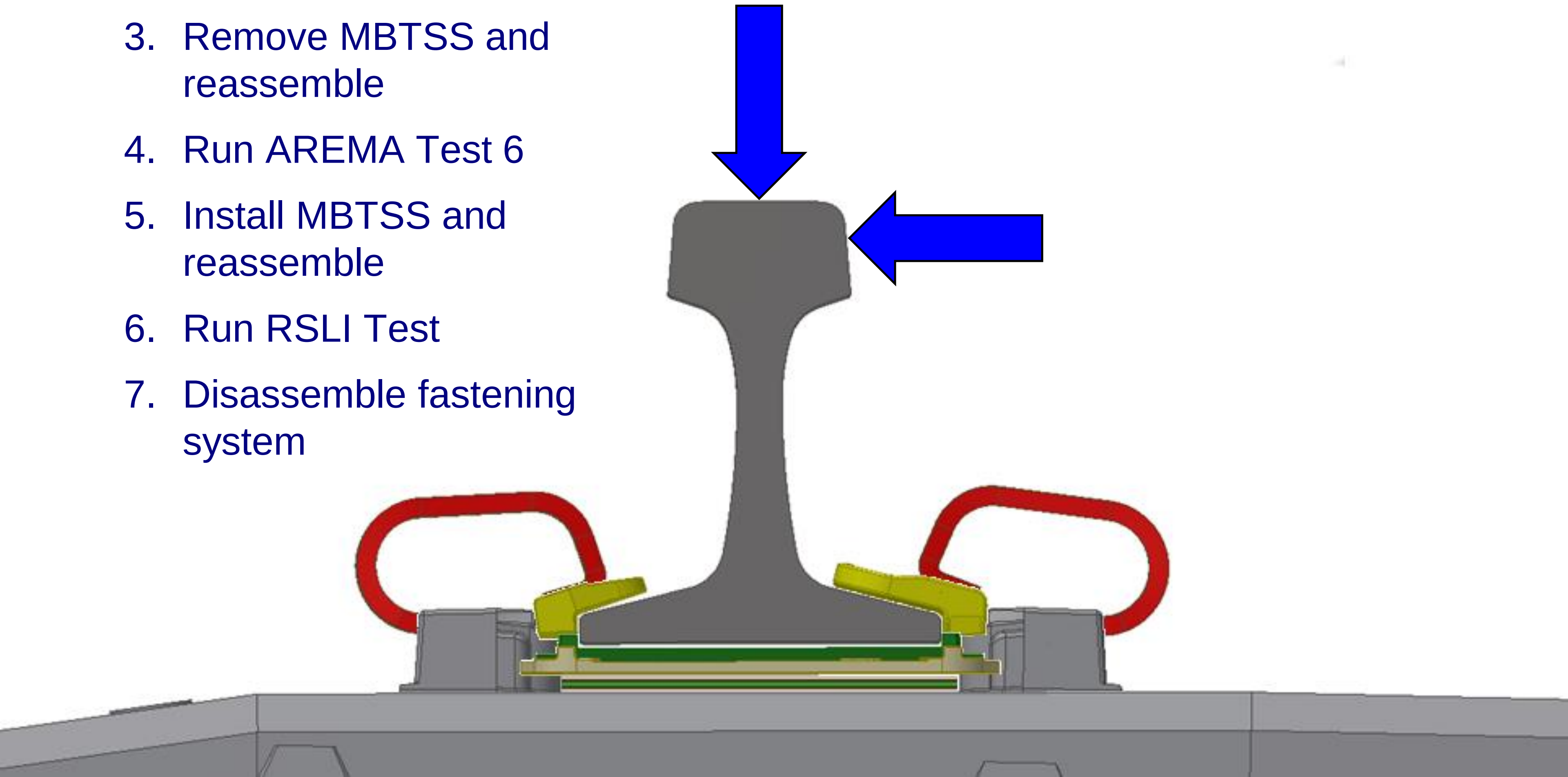


Proposed RSLI Test

- Assembly-level verification in the mechanistic design process
- To be conducted in conjunction with AREMA Test 6:
  - RSLI obtained with MBTSS before and after Test 6
  - Vertical and lateral loads to be determined by end user
    - Default is 40 kips vertical, 0 to 0.6 L/V
  - Pass/Fail criteria based on change in RSLI and absolute limits
    - Thresholds mechanistically determined based on field performance and RSD failure mechanisms
- Test will require fastening system to be disassembled and reassembled twice between tests to remove and install MBTSS

Proposed RSLI Test

1. Assemble fastening system with MBTSS
2. Run RSLI test
3. Remove MBTSS and reassemble
4. Run AREMA Test 6
5. Install MBTSS and reassemble
6. Run RSLI Test
7. Disassemble fastening system



Industry Impacts

- RSLI encourages fastening system designs that:
  - Restrict rail rotation at design L/V ratios
  - Resist excessive wear of field-side lateral load-bearing system and gauge-side fastener
  - Reduce severity of failure mechanisms associated with RSD

Conclusions

- Rail seat load distribution is highly non-uniform
- Current design practice does not adequately capture the behavior of the rail seat load distribution
- Poor fastening system health significantly affects rail seat load distribution
  - 40% reduction in contact area to 22.67 in^2 (146.3 cm^2)
  - 71% increase in average pressure to 899 psi (6.2 MPa)
  - 60% increase in maximum pressure to 2,349 psi (162 MPa)
- The portion of the rail seat 1 inch (25.4 mm) from field side is the region most sensitive to changes in L/V force ratio
- RSLI provides a mechanistic evaluation of rail seat load sensitivity
- Application of RSLI to tie and fastening system design practices may result in designs more resistant to RSD

Future Work

- How do fines and small particles affect the rail seat load distribution?
- Can we quantify the relationship between fastening system wear and change in rail seat load distribution?
- Can we correlate load nonuniformity to RSD?
  - How does rail seat pressure correlate to damage?
  - How does rail seat pressure correlate to crosstie life expectancy?

Acknowledgements

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