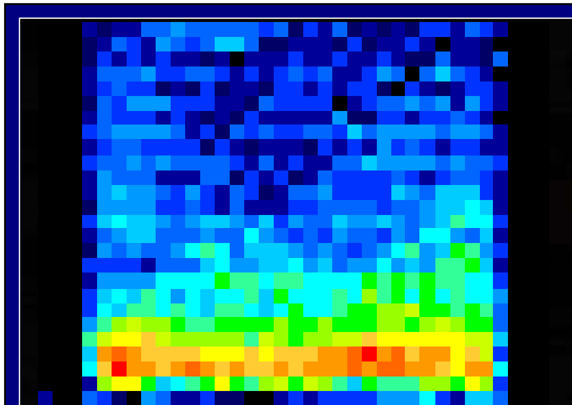
Effect of Rail Seat Deterioration on Rail Seat Load Distributions



Committee 30, Subcommittee 4 Presentation

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Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TTCI
Transportation Technology Center, Inc.

Amsted RPS
An Amsted Rail Company

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

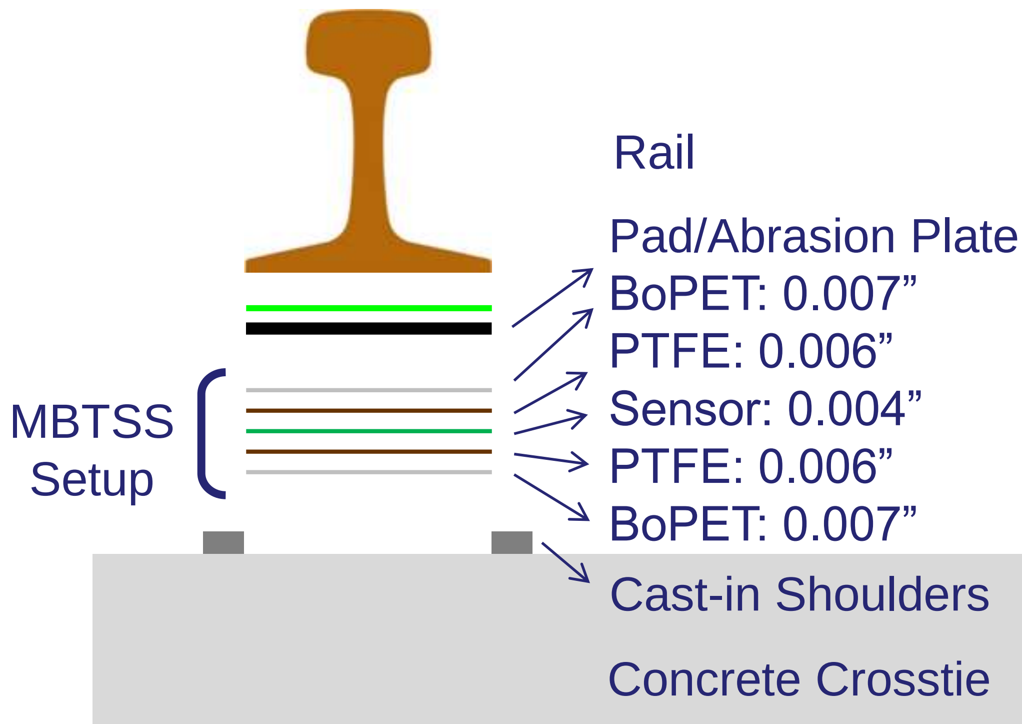
- Quantify effect of RSD wear shape and depth on rail seat load distribution
- Correlate rail base rotation to excessive rail seat pressure
  - Encourage mechanistically-defined inspection thresholds to detect unsafe levels of RSD
- Use relationships to guide thresholds for proposed rail seat load distribution design metric

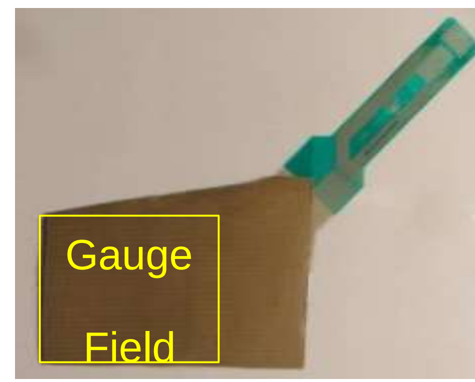
Rail Seat Deterioration Background

- 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



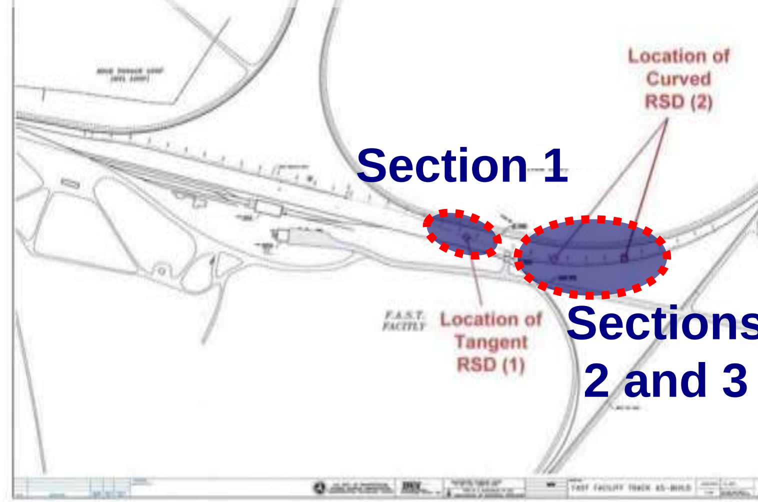


Plan View of Sensor and Protective Layers

Field Experiment Program

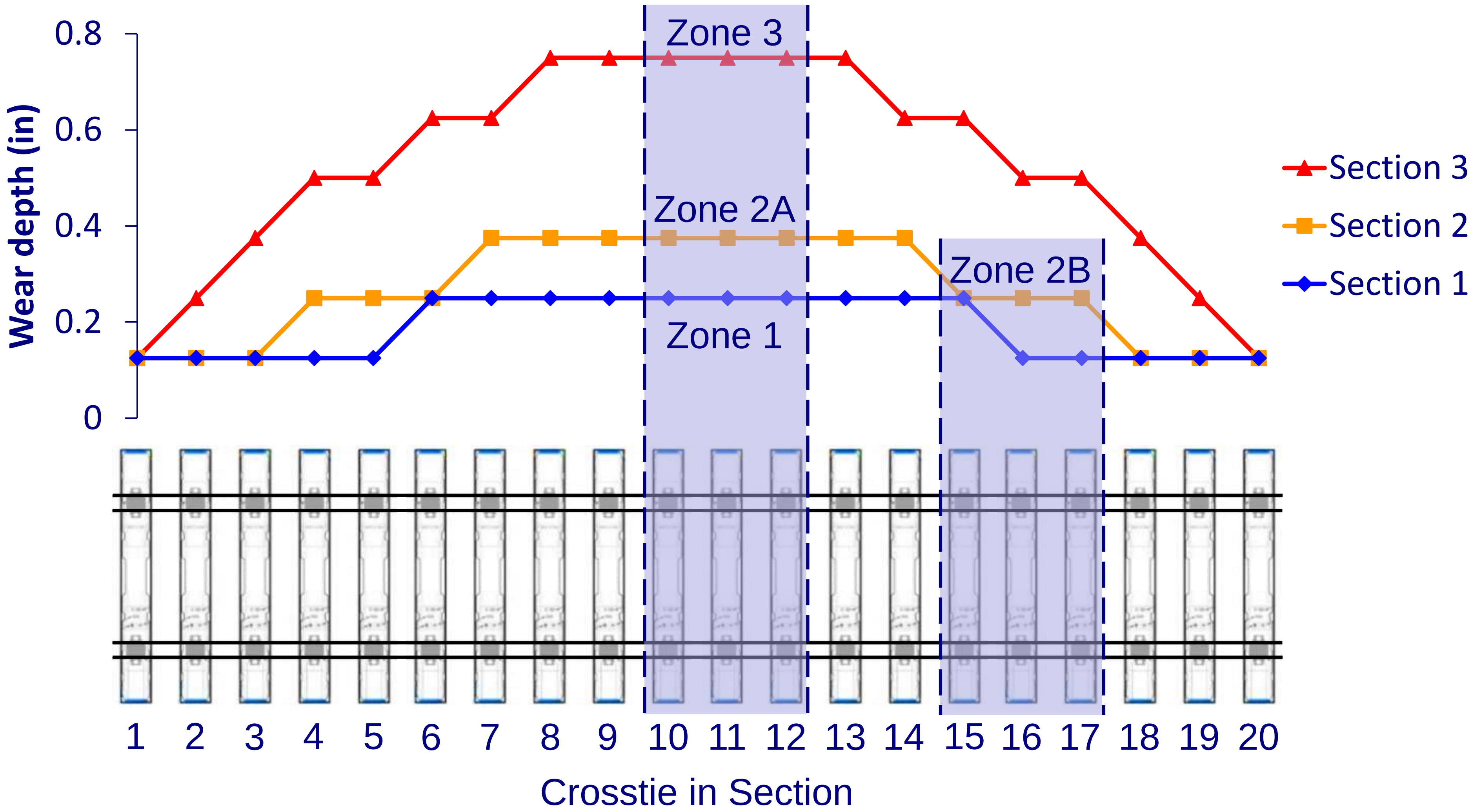
- **Objective:** Analyze the effect of RSD depth and shape on rail seat load distribution and correlate to rail base rotation
- **Location:** Transportation Technology Center (TTC) in Pueblo, CO
  - **Section 1:** tangent section with 1/4 inch uniform wear
  - **Sections 2 and 3:** curved sections with 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

Transportation Technology Center (TTC)

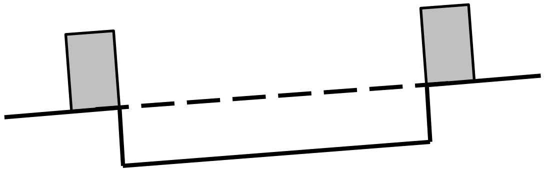


DOTX 218 (T-18)

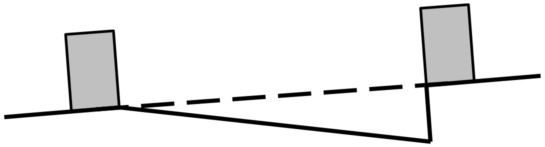
RSD Section Wear Depths



Rail Seat Wear Profiles



Uniform Wear (Zone 1)



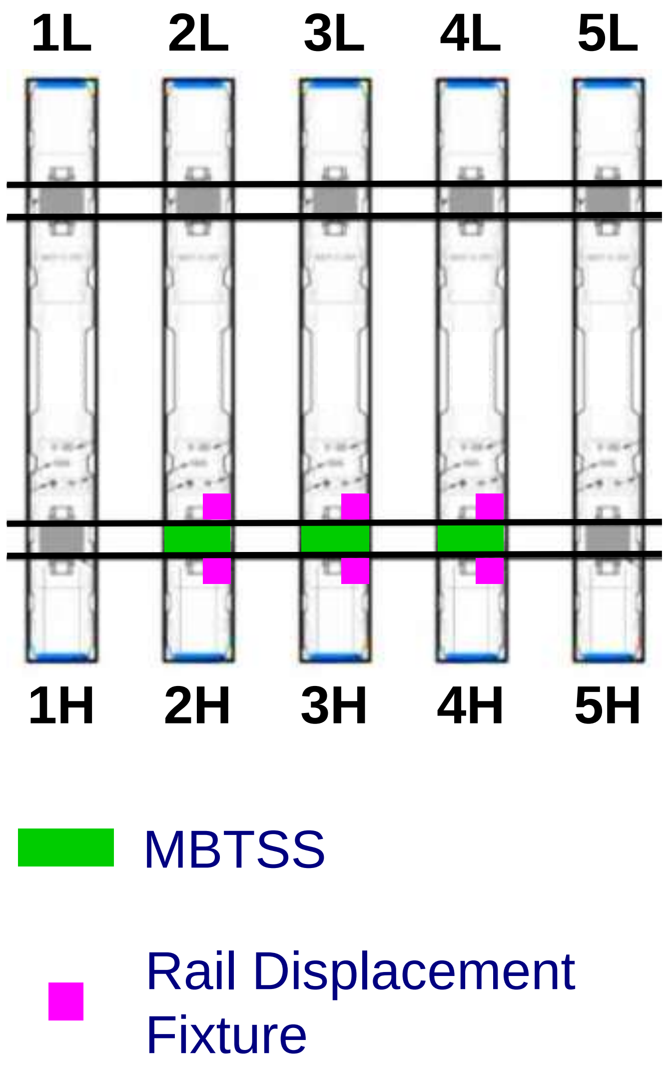
Triangular Wear (Zone 2A, 2B, 3)

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

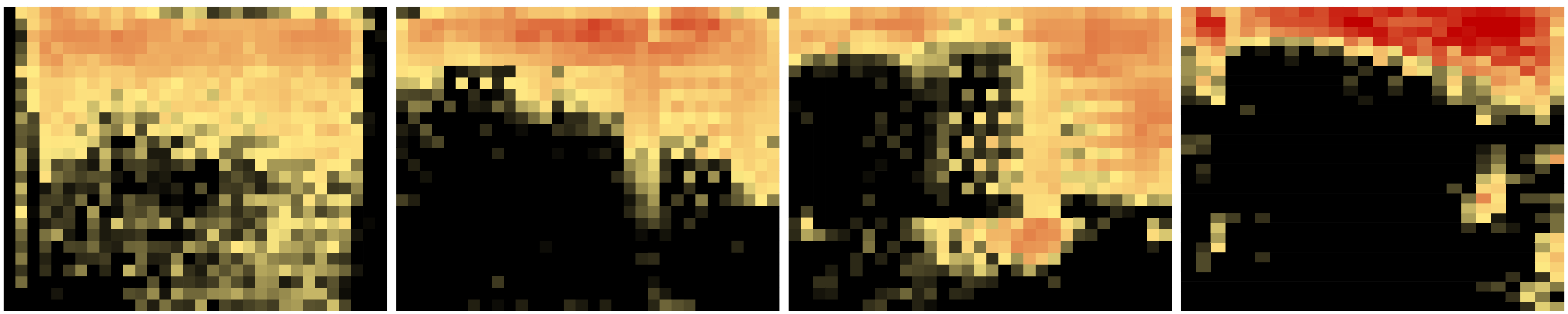
- 20,000 lb (88.9 kN) vertical load constant for all tests
- Static tests:
  - L/V force ratios of 0 to 0.8 at 0.2 L/V intervals
  - Load applied at all 3 instrumented rail seats, as well as one rail seat on either side of instrumentation zone
- Dynamic tests:
  - L/V Force ratios of 0, 0.4, and 0.8
  - Conducted at 5 and 15 mph

Rail Seat Load Concentration

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

0” Wear (May 2013) | **1/4” Triangular Wear** | **3/8” Triangular Wear** | **3/4” Triangular Wear**

Field



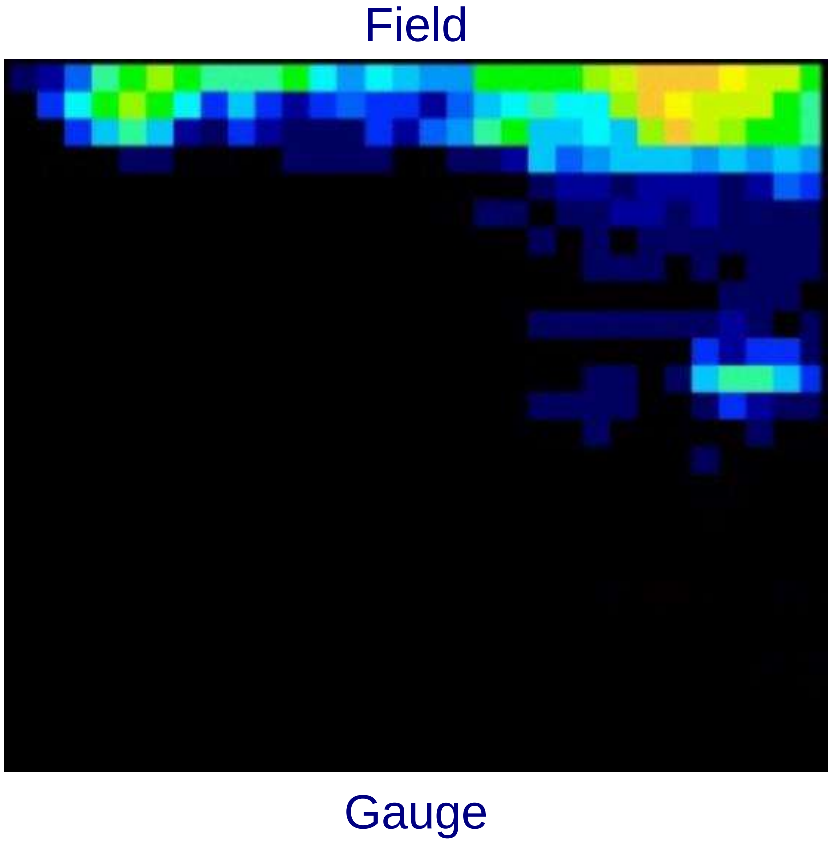
Gauge

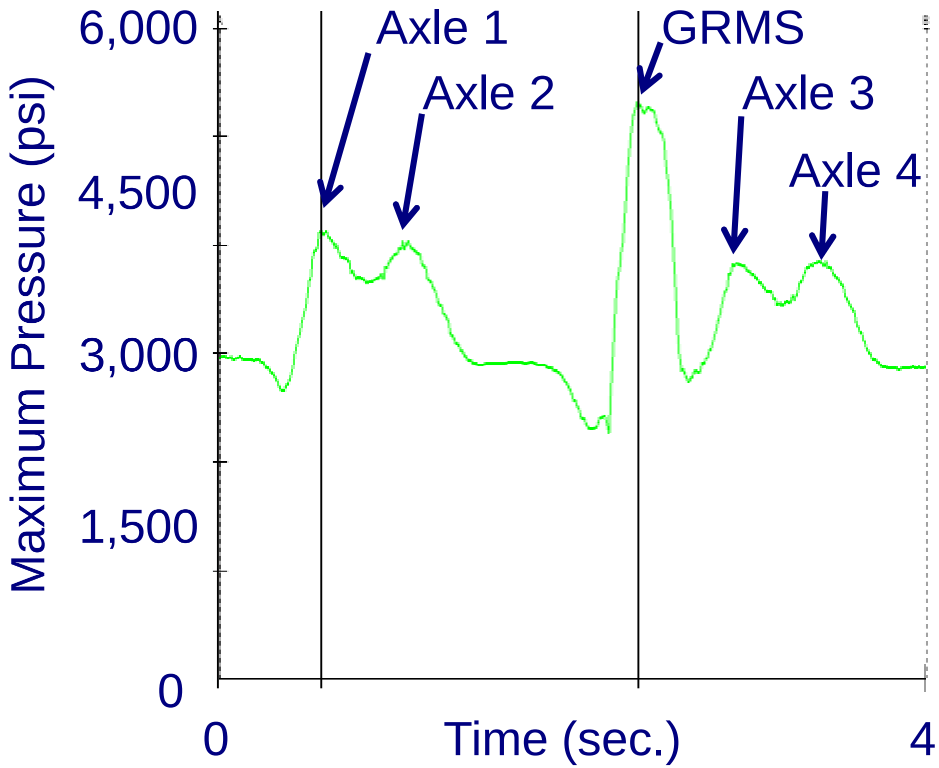
- General trend of increasing load concentration toward field side of rail seat with increased wear depth
- Trend of load concentration on right side of rail seat

T-18 Dynamic Run

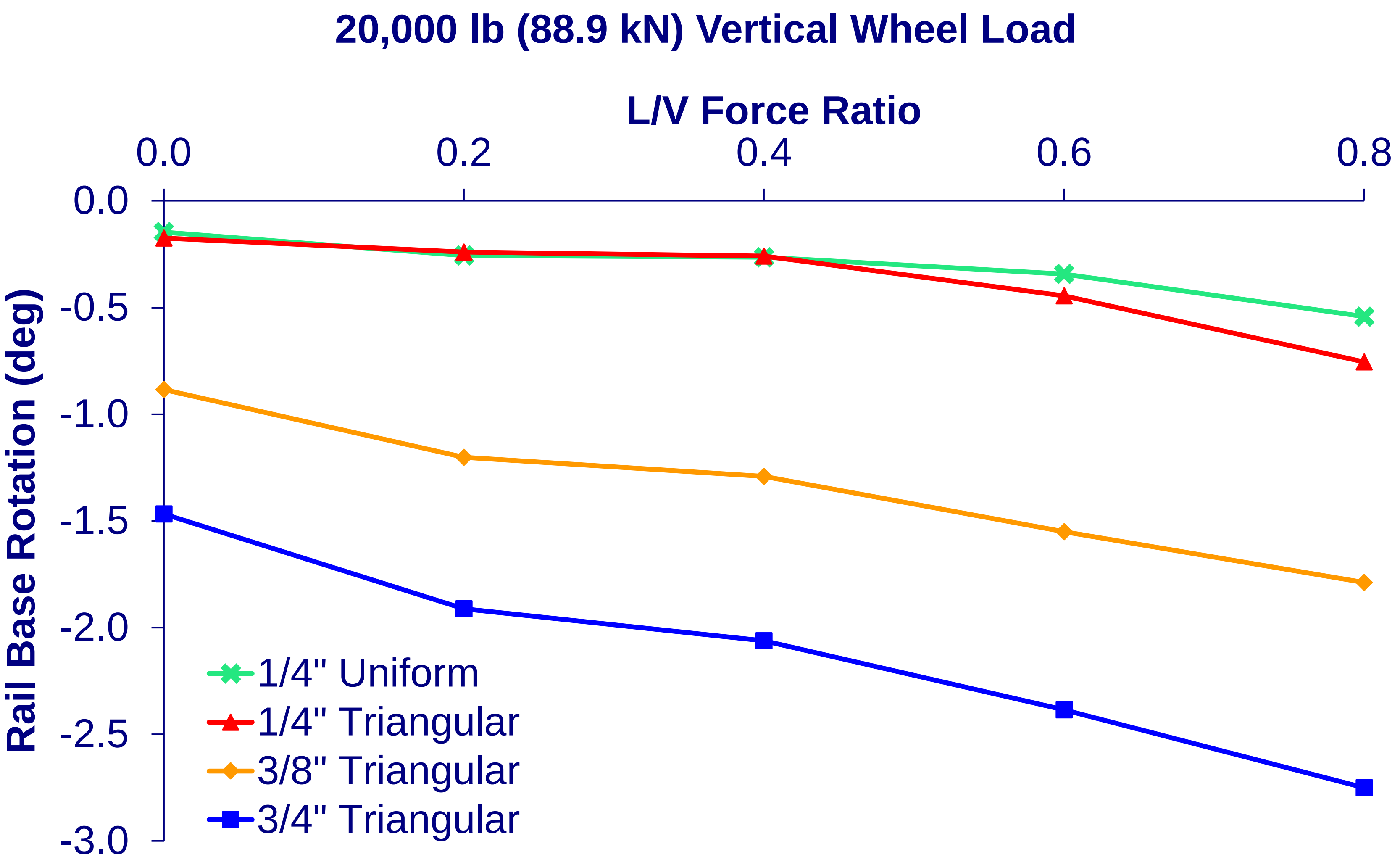
20,000 lb (88.9 kN) Vertical Wheel Load, 0.8 L/V Force Ratio

3/4" Wear, 15 mph

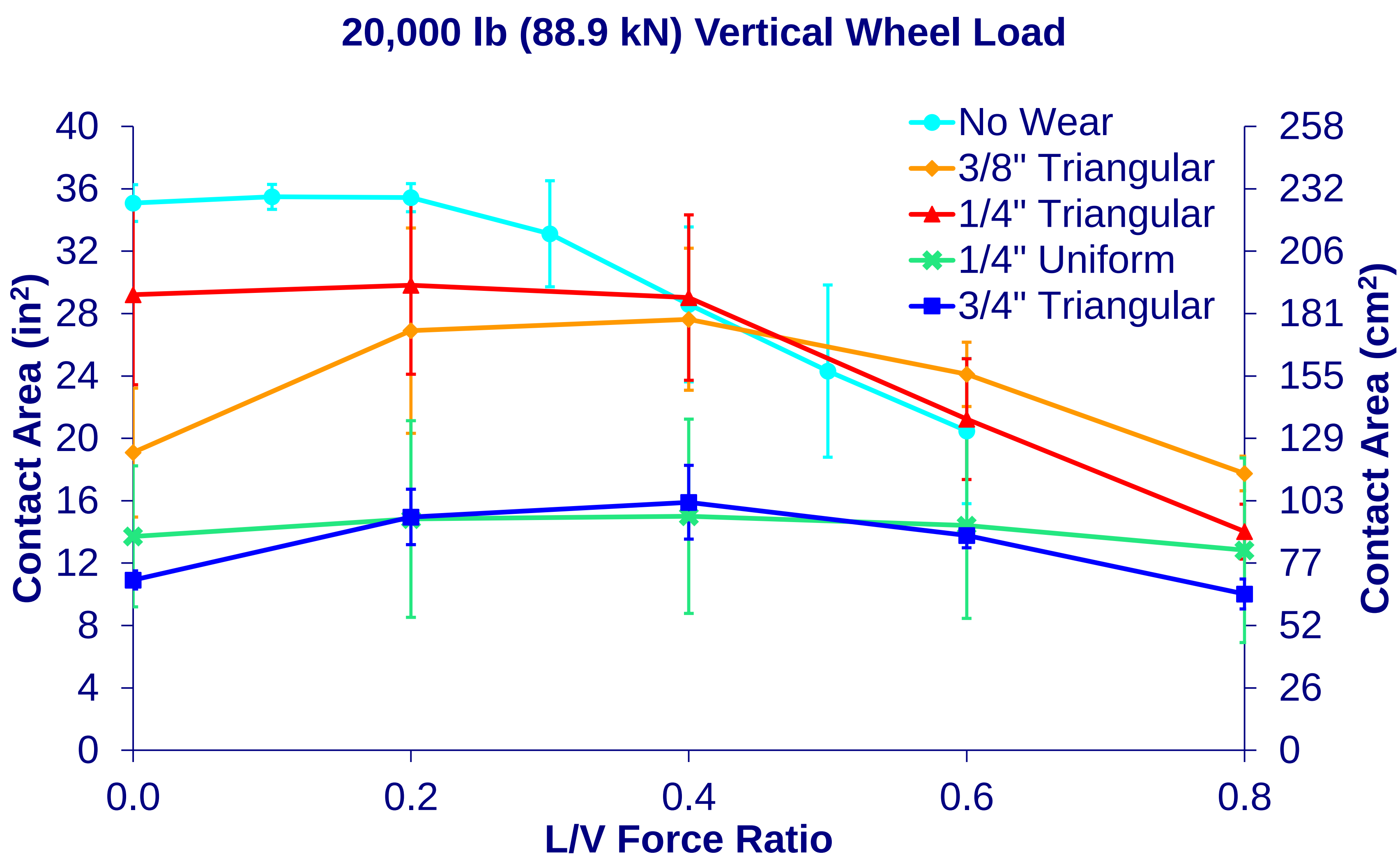




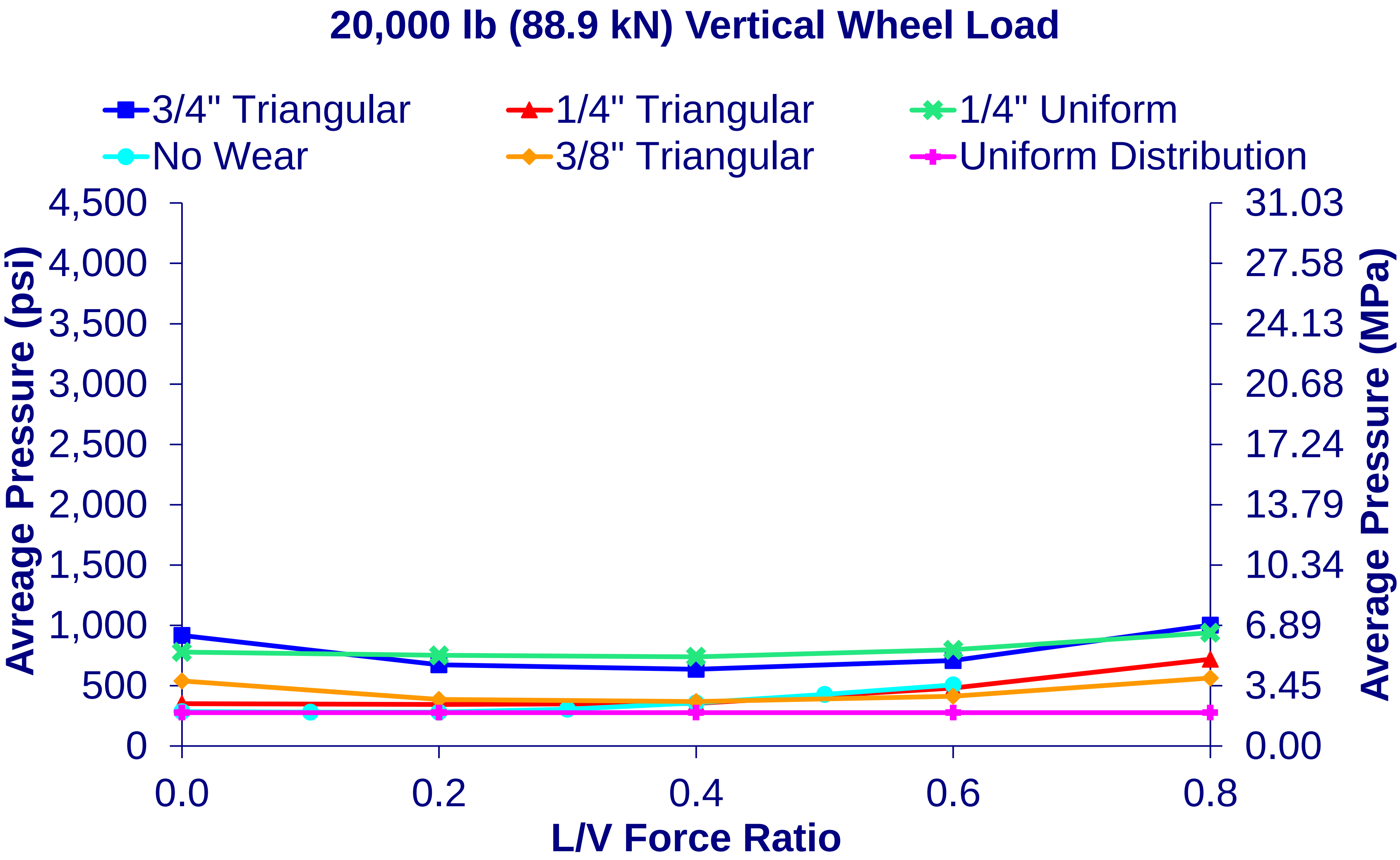
Effect of L/V Force Ratio on Rail Base Rotation



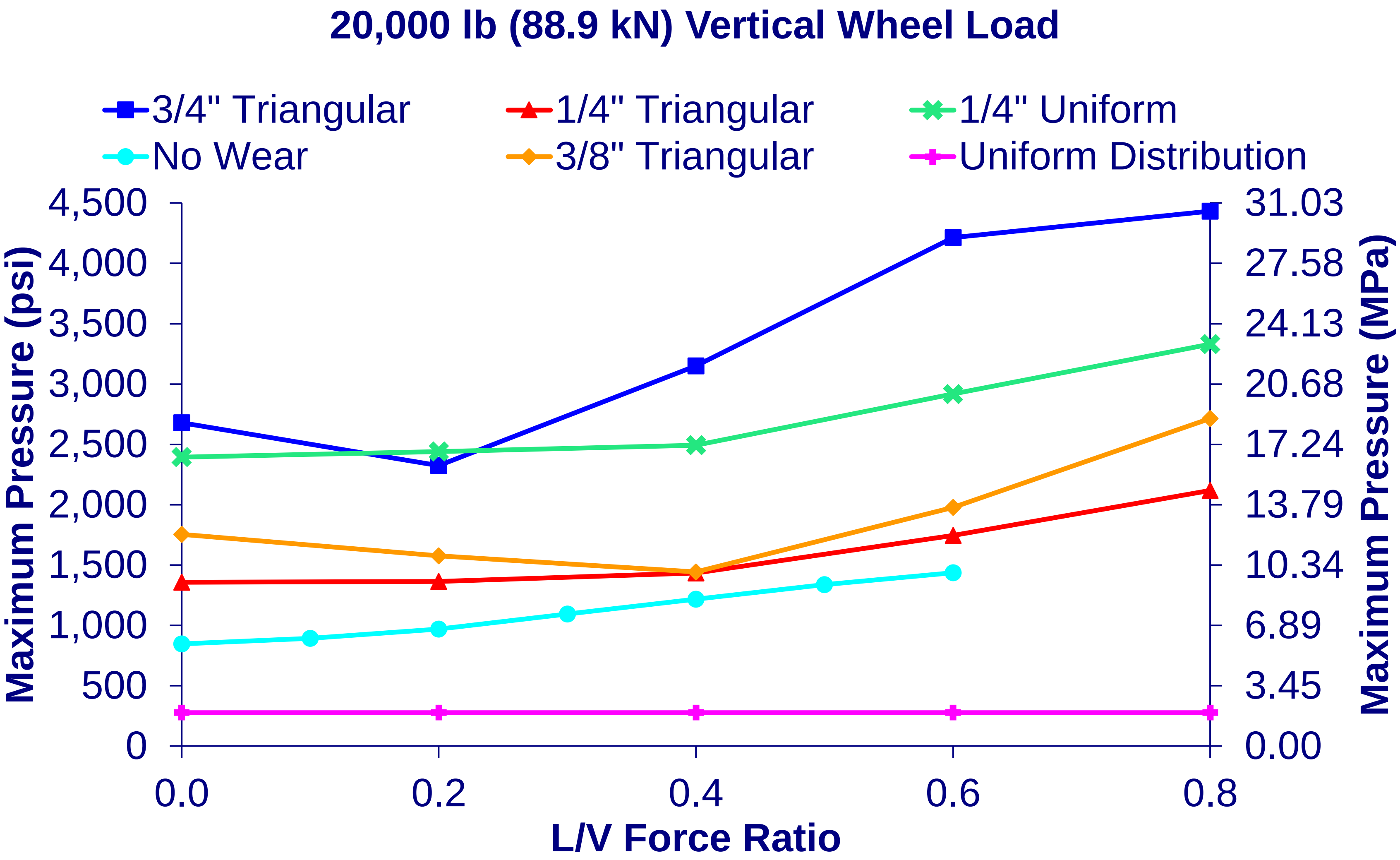
Loss of Contact Area



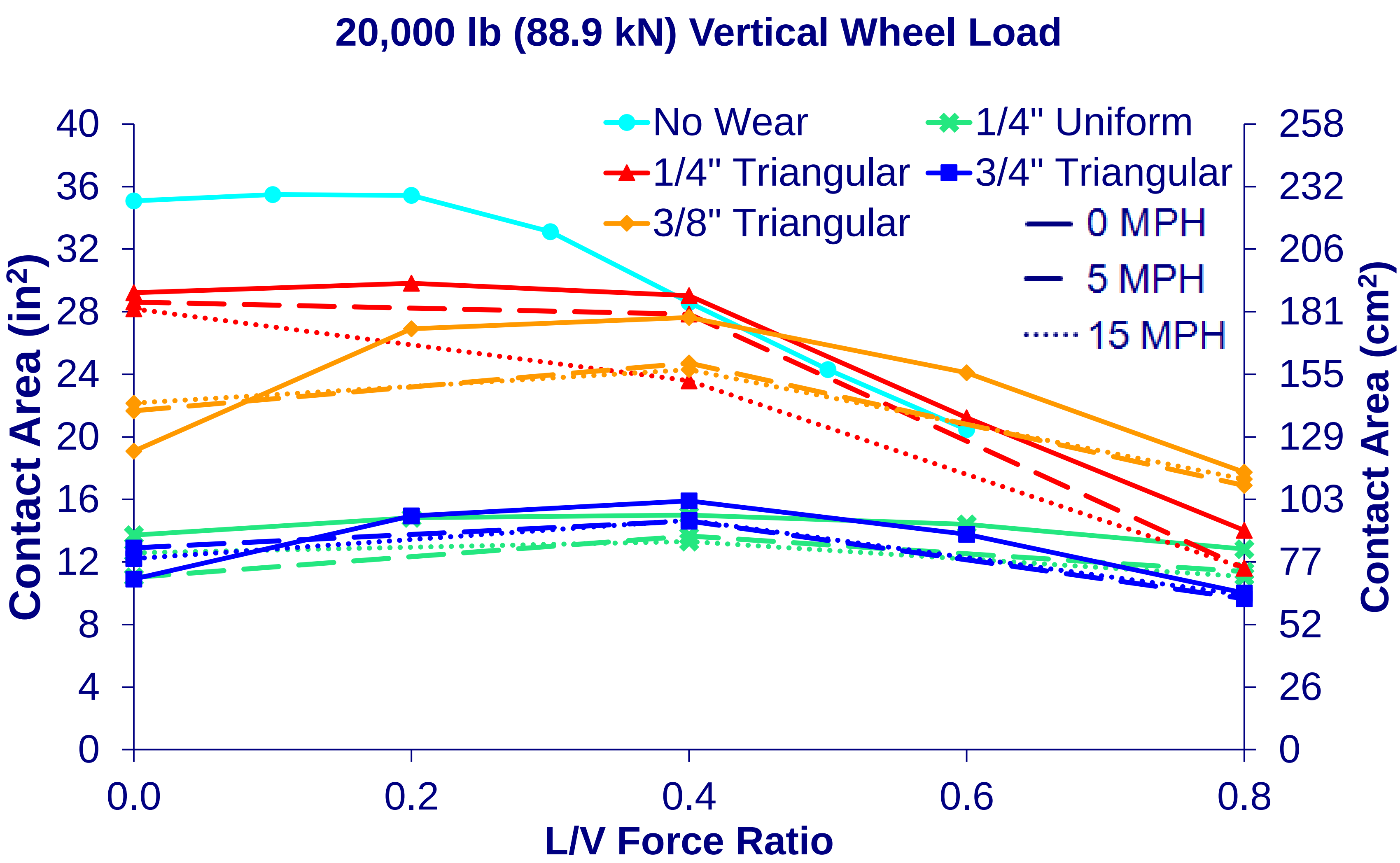
Effect of Wear Depth on Average Pressure



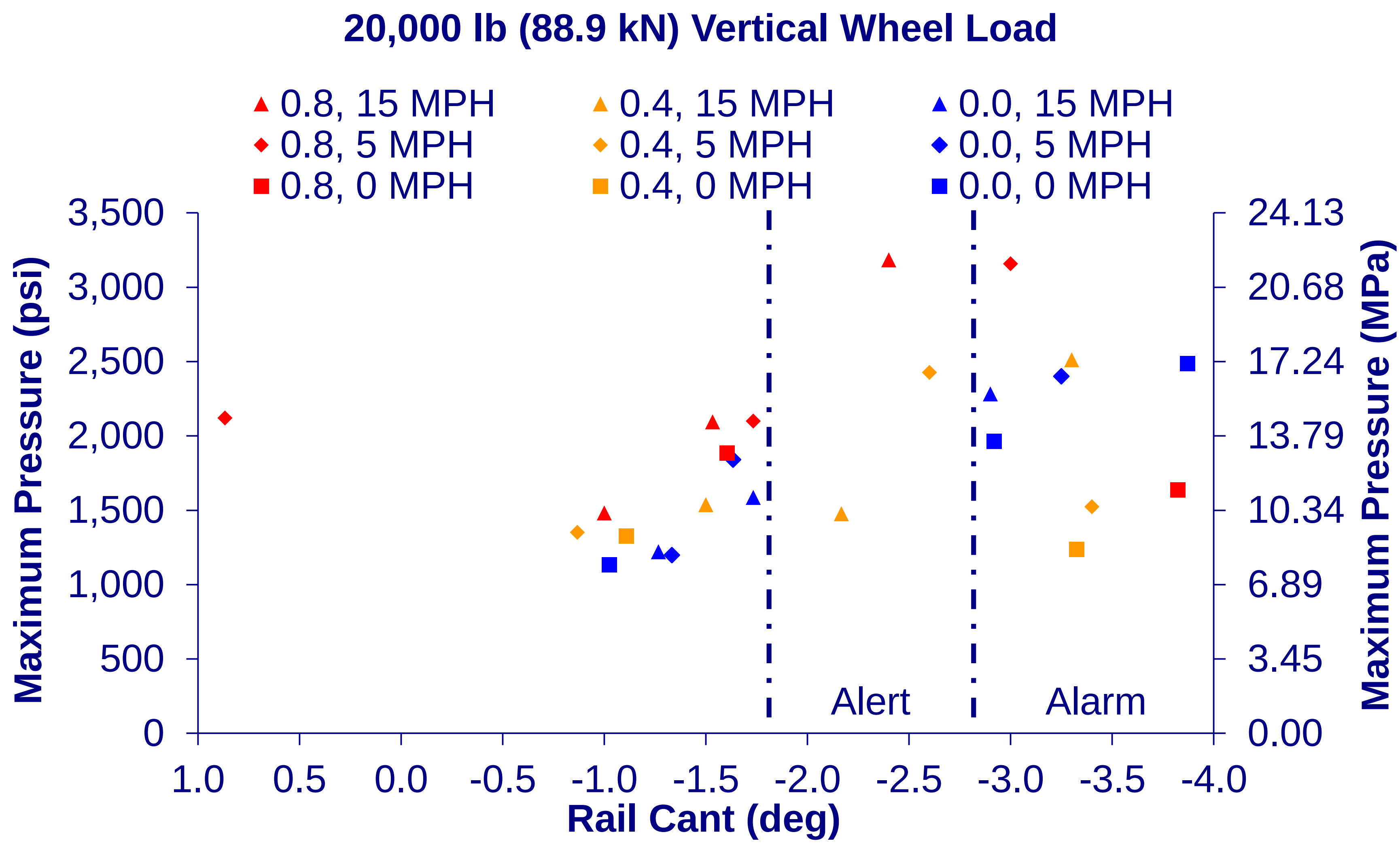
Effect of Wear Depth on Maximum Pressure



Effect of Speed on Contact Area



Relationship between Rail Cant and Maximum Pressure



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?

Acknowledgements

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