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Rolling contact fatigue in heavy haul railroads - conclusions from an extensive pummelling simulation

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Outline

- Approach
- Measured Data
- Sensitivity Analysis
- Challenges & Limitations
- Methodology
- Results
- Analysis
- Conclusions & Observations
- Next step

Approach

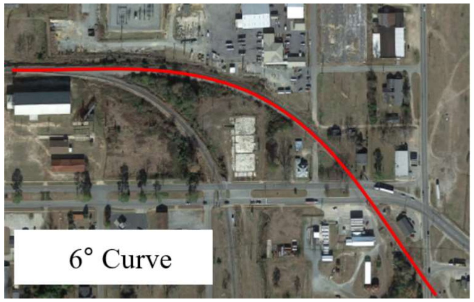
- Collected North American freight data on test locations
- Developed real world loading conditions on railway track using NRC's stochastic multi-body dynamic modelling and tens of thousands of simulations
- Provided the necessary modelling outputs for application into rail surface damage models and provided the relevant data for validation against field observations
- Developed MATLAB program and conducted study for pummelling and sensitive analysis of the stochastic simulation results which are presented in statistical tables, heat maps, 3-D and 2-D plots

Measured Data
(data package available upon request)

- Rail profiles measured using an optical system on board a hy-rail vehicle
- Track geometry obtained from geometry car
- Wheel profiles measured on various types of cars
- Traffic type, weight and speed data from WILD site
- Rail friction coefficients obtained with tribometer measurements
- MRX crack depth measurements on each rail
- Rail surface photographs taken along the track

Sensitivity Analysis

Based on stochastic simulation results, sensitivity analysis has been undertaken to understand the effect of various factors on RCF, wear and stress including:



- Train speeds
- Car types
- Car weights
- Friction conditions
- Effect of wheel profiles (e.g. new vs. well-worn vs. hollow-worn wheels)
- Changes in rail profiles (e.g. changes as-measured from one foot to the next)

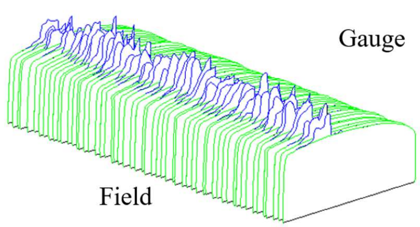
Challenges & Limitations

While useful for rail surface damage modelling and validation against field measurements, using existing stochastic simulation results for sensitivity analysis has some challenges, such as

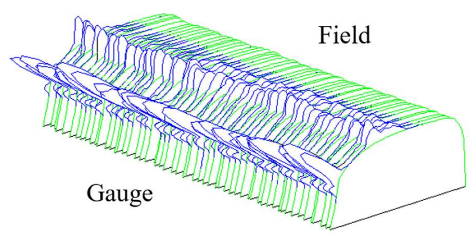
- Due to the nature of our stochastic simulation, outlier cases are less represented in the sensitivity analysis. This leads to lower confidence in the results of edge cases.
- Narrow range for some of the categories. For example, the friction ranges for top of rail and flange are quite narrow as the case in reality.
- It is challenging to study the impact of one factor on damage modelling while all other factors are changing simultaneously.

Methodology – Rail Pummelling Envelope

Rail pummelling is the process of subjecting a rail profile to a distribution of wheel loads as it would be expected to encounter in service. Through simulation, cars with a wide range of vehicle, profile, friction and operating conditions can run over a track. The simulation results, such as positions of the wheelsets, wheel-rail contact shapes and positions, contact stresses, creepages, forces and wear numbers (Tγ) along a track, are used to calculate and display the accumulated distributions (envelopes) of contact conditions, such as contact stress, wear and RCF, across the rail and along the track.



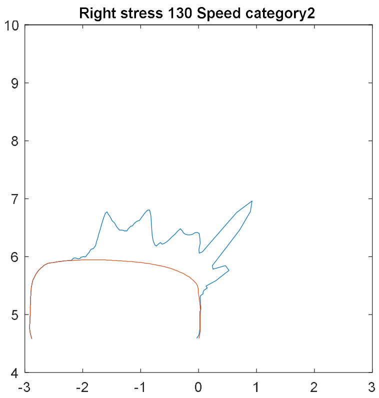
Wear on low rail

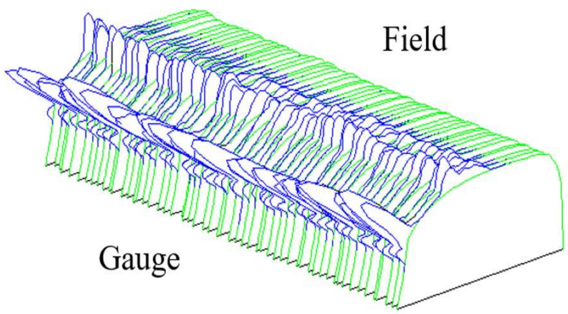


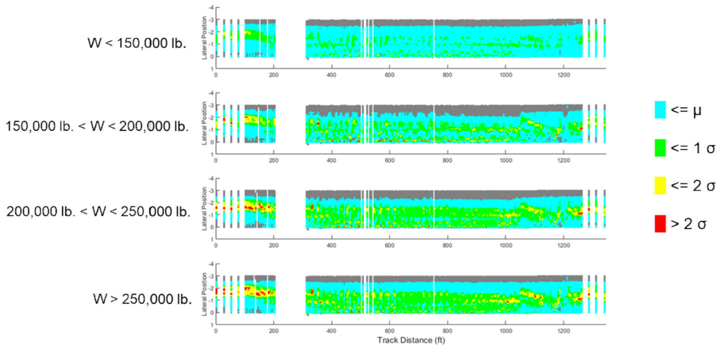
Wear on high rail

Methodology – Establishing and Comparing Categories

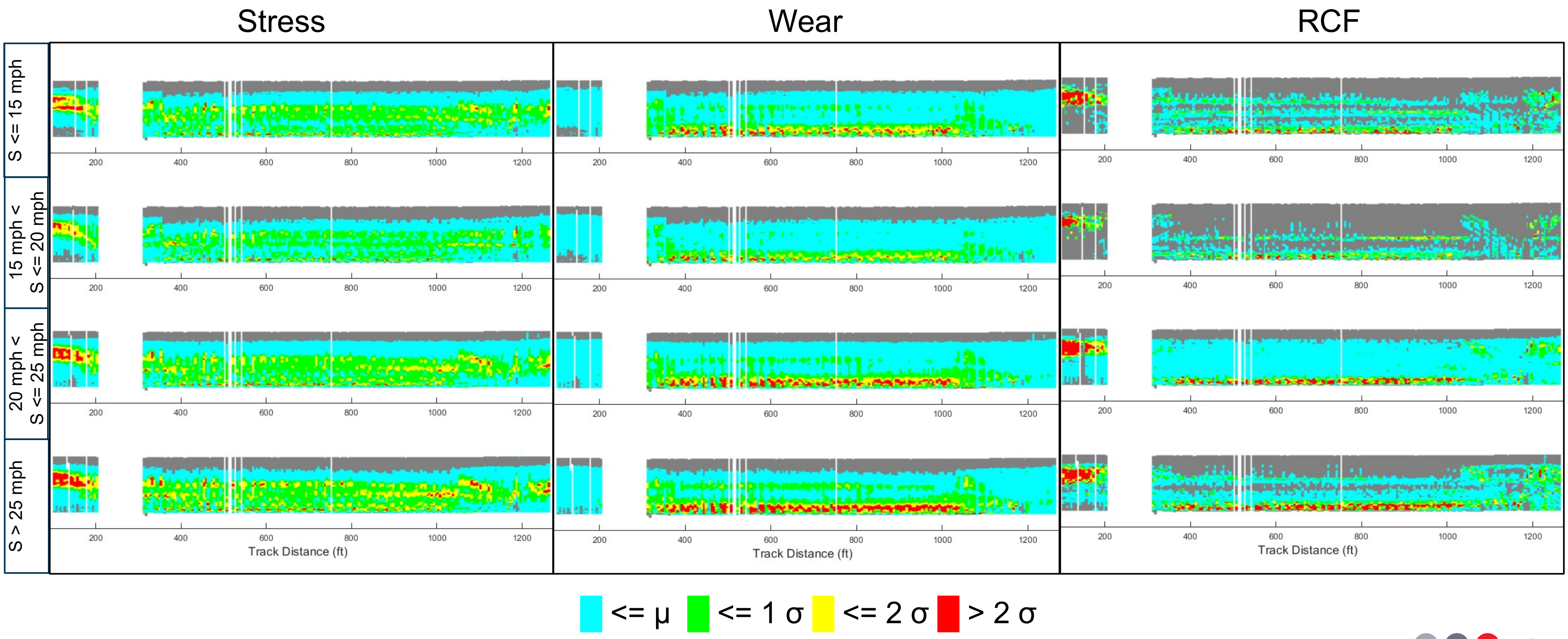
- 3 performance metrics: RCF index, wear (Tγ), and contact stress
- 4 categories: speed, weight, friction, and wheel wear state



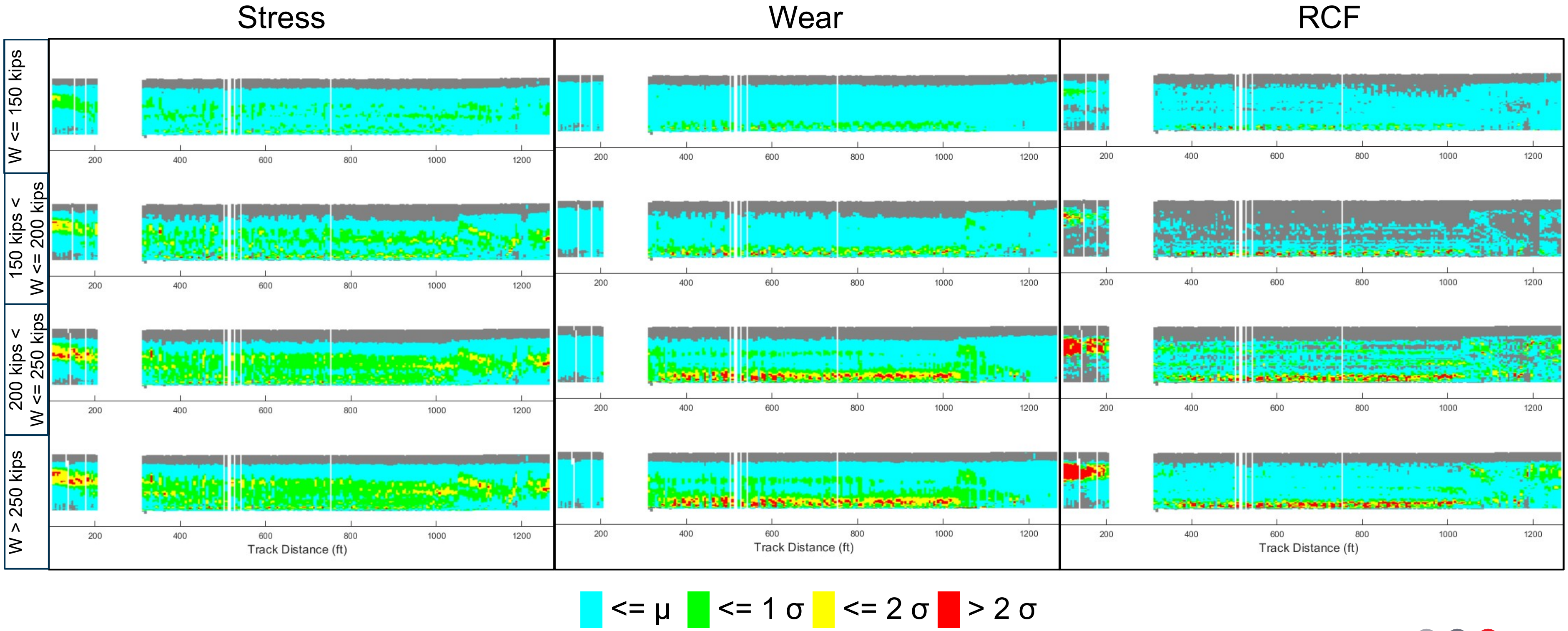




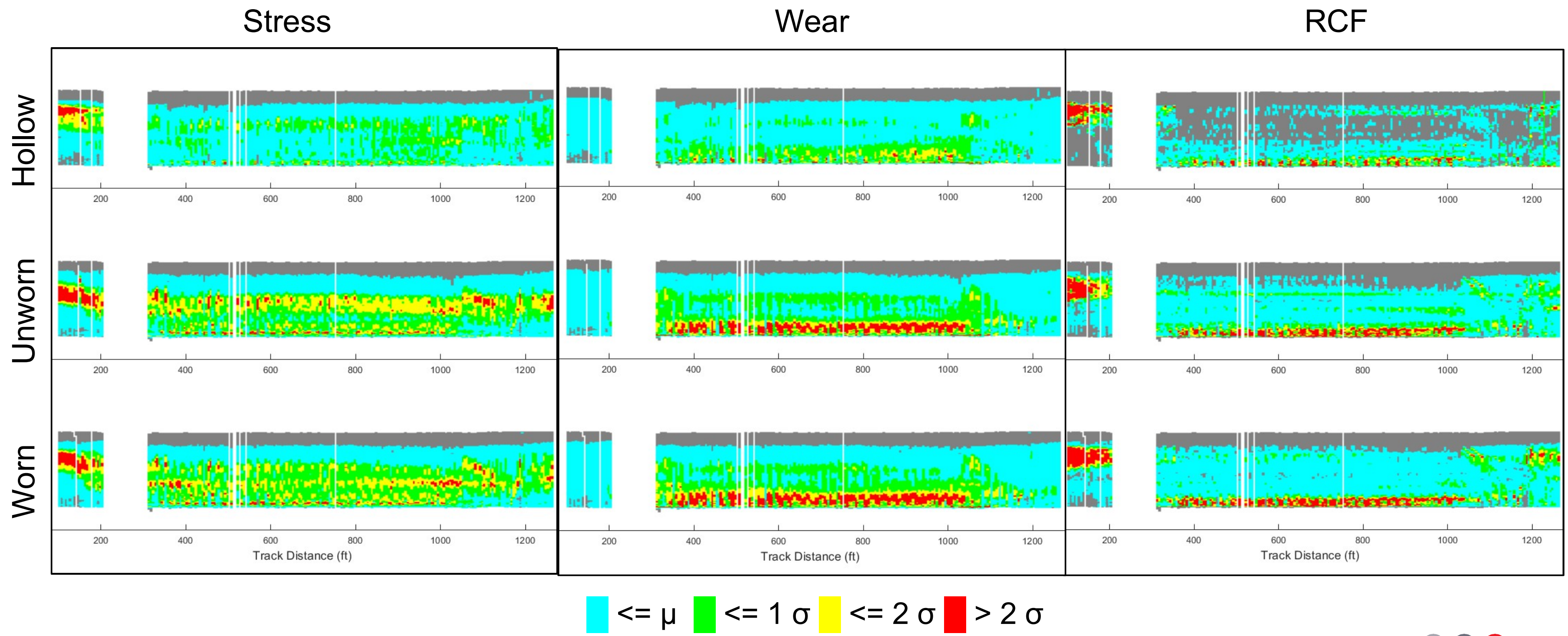
Results - Effect of Speed



Results - Effect of Weight

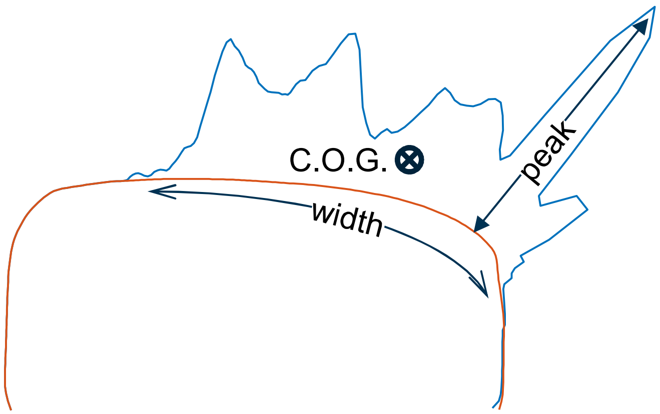


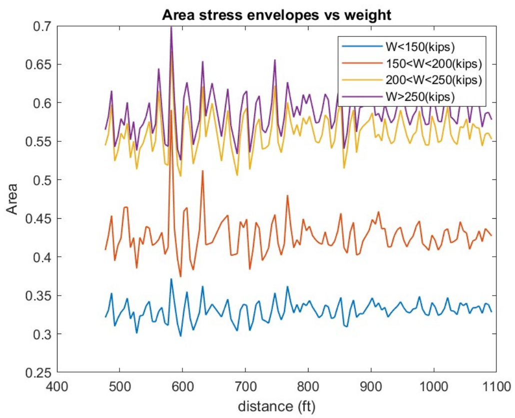
Results - Effect of Wheel Profile

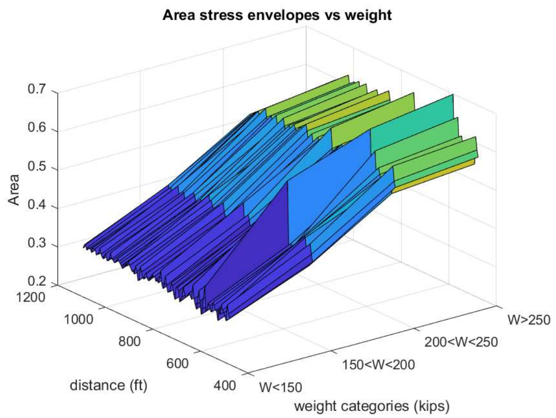


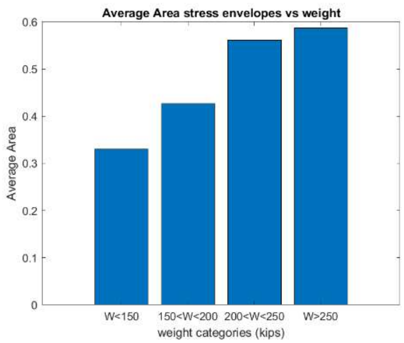
Analysis - Quantifying the Envelope

- **5 envelope metrics:** COG x and y, peak value, area, and width
- **Viewing data: 2-D and 3-D plots of each metric, bar charts of mean, max, min, and std. dev.**

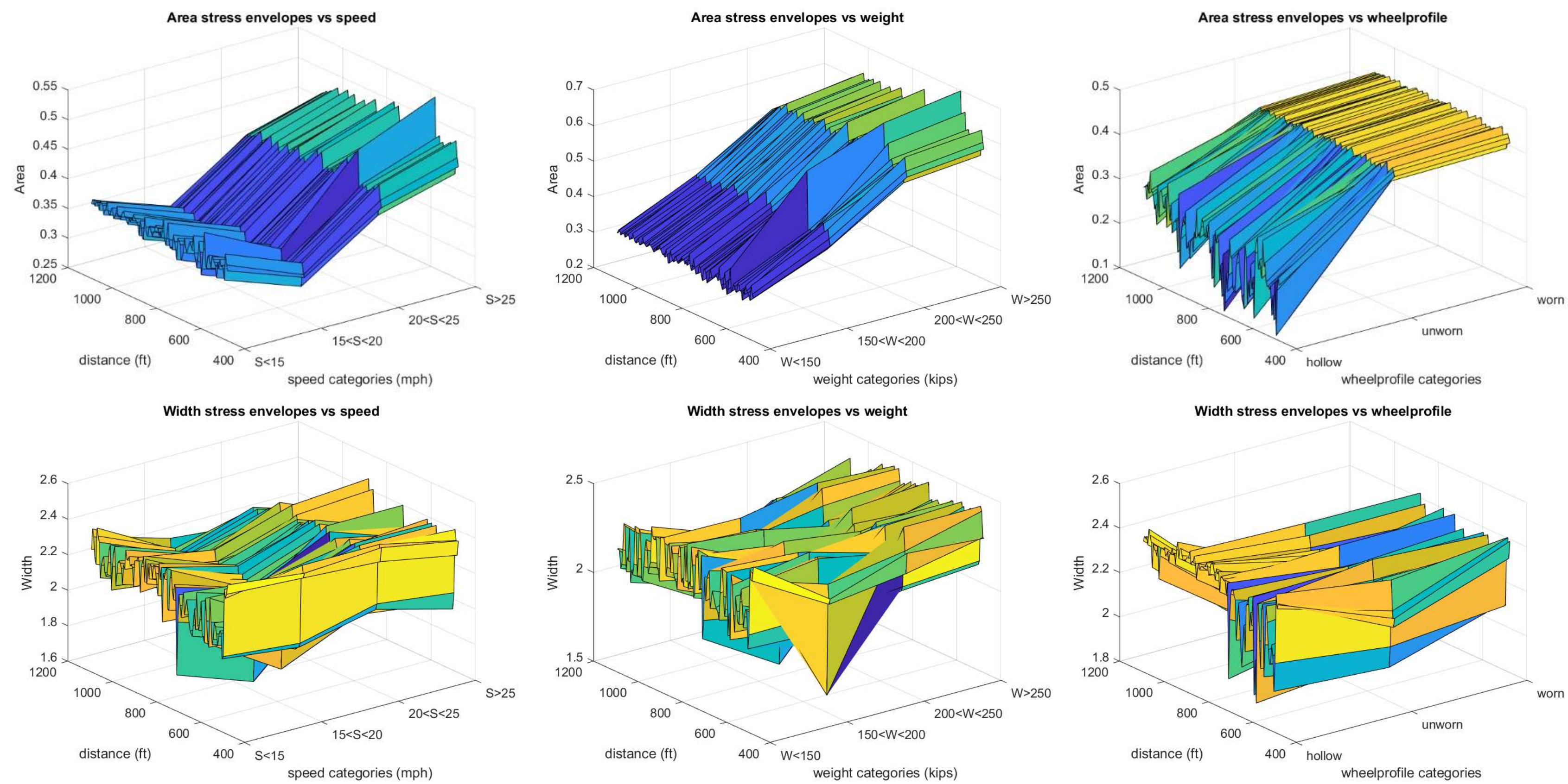




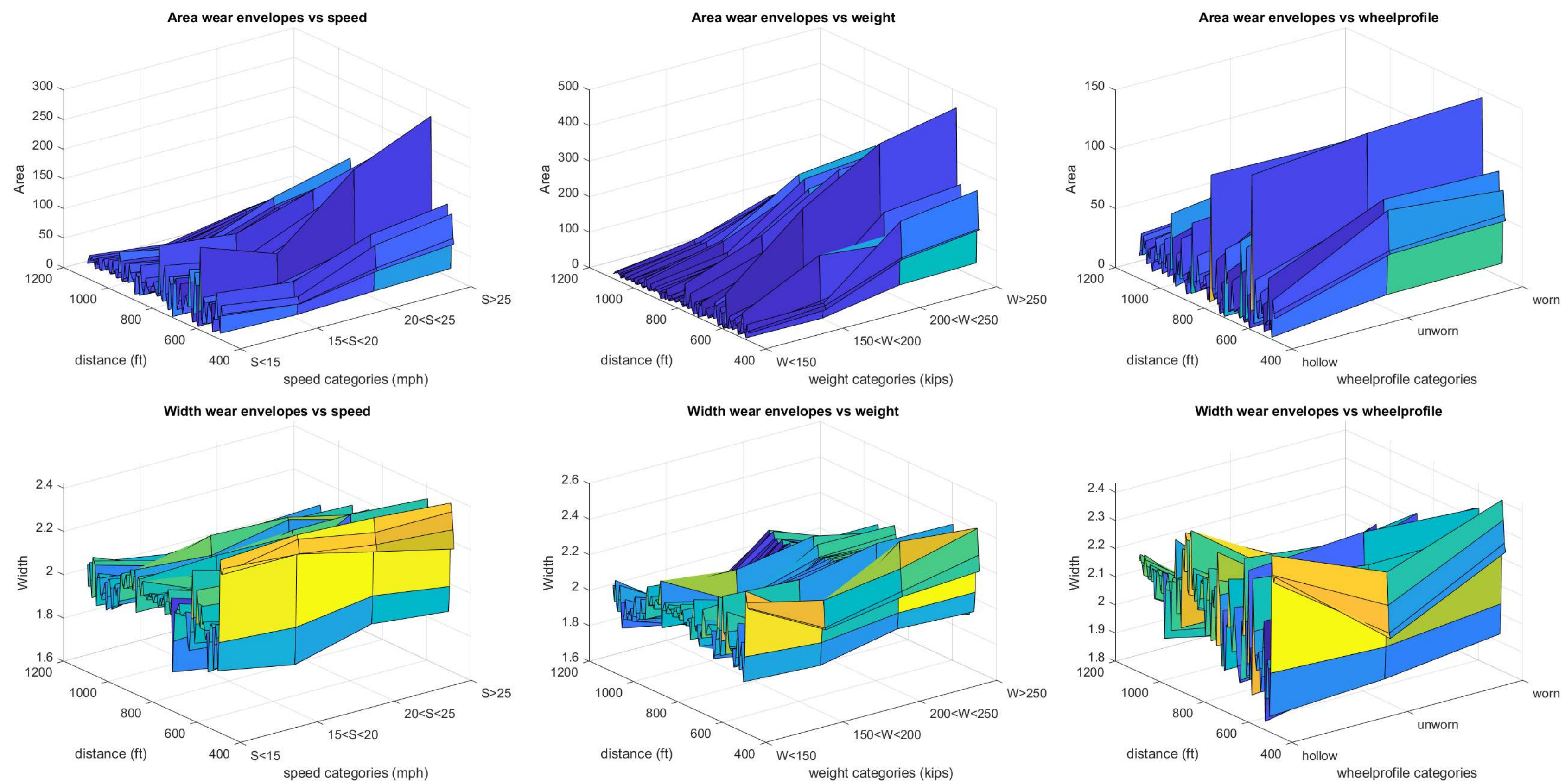




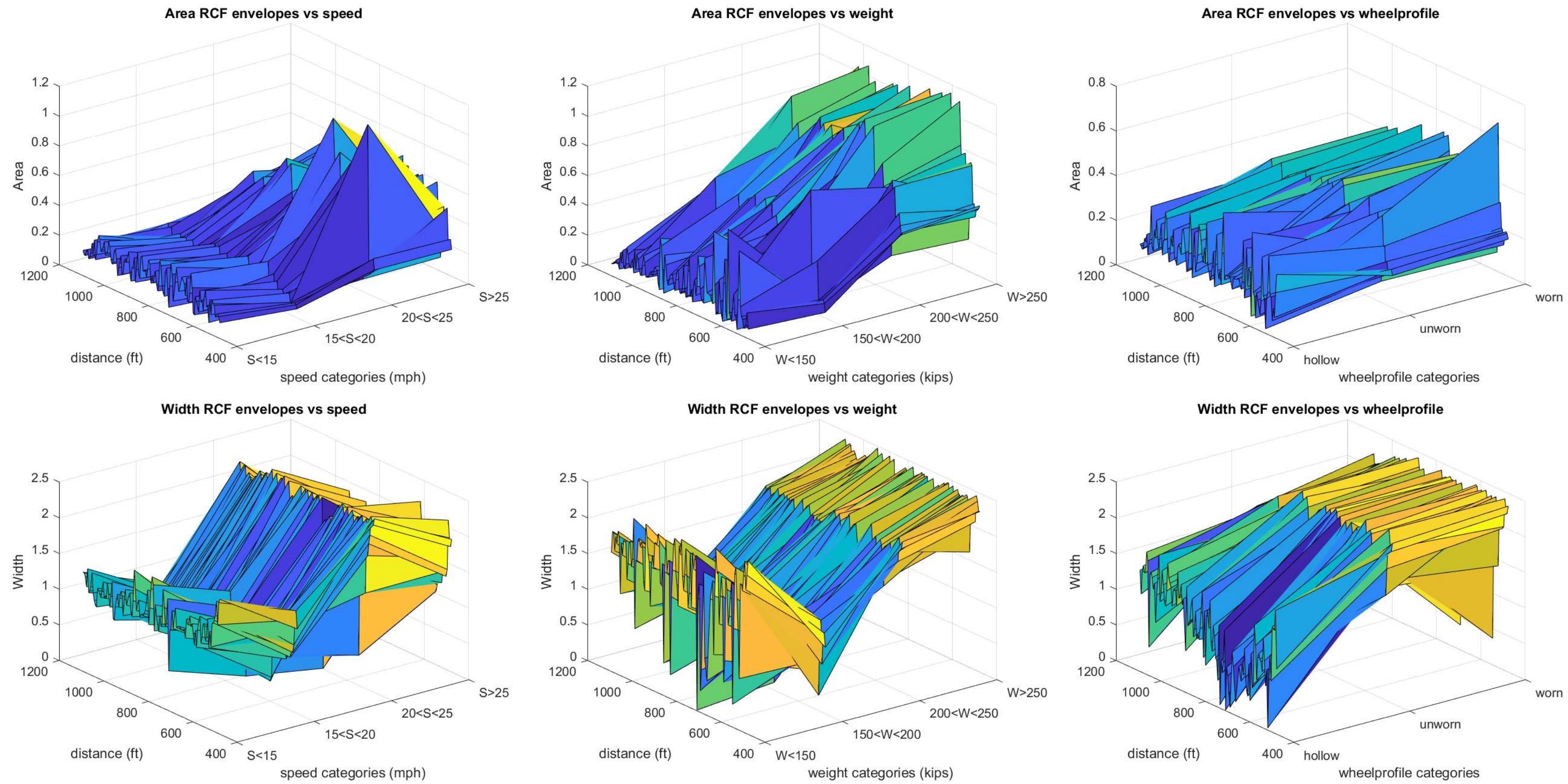
Analysis - Pummelling Envelope Area and Width vs. Contact Stress



Analysis - Pummelling Envelope Area and Width vs. Wear

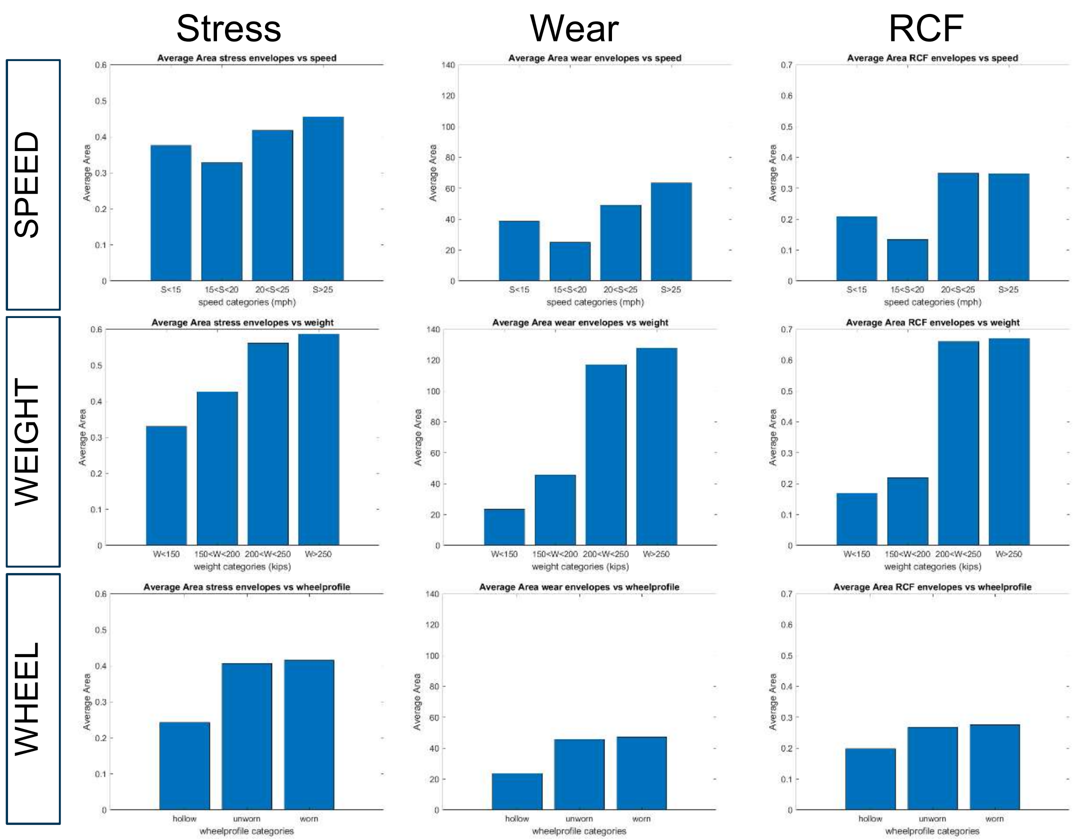


Analysis - Pummelling Envelope Area and Width vs. RCF



Conclusions and Observations

- Best approach: use average area of each category over length of rail
- Envelope area is our current approximation of heat map observations but needs to be improved to capture more information
- Contact stress, wear, and RCF index are more sensitive to increases in weight
- Non-linear relationship with speed requires investigation. Possibly due to balance speed.



Next Steps

Broaden scope of simulation data

- Extra curves and tangents
- Wider input ranges of factors, like friction, and use more evenly-distributed input distributions rather than distributions based on real-world data
- Higher number of simulations runs

Expand and refine the selection of wheel-rail performance metrics and envelope metric

Improve post-processing software performance

Improve results plotting

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THANK YOU

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