

Rail/Vehicle Simulations to Quantify Loading Environment for Damage Modelling

Wei Huang, Alexandre Woelfle and Alok Jahagirdar
October 2018



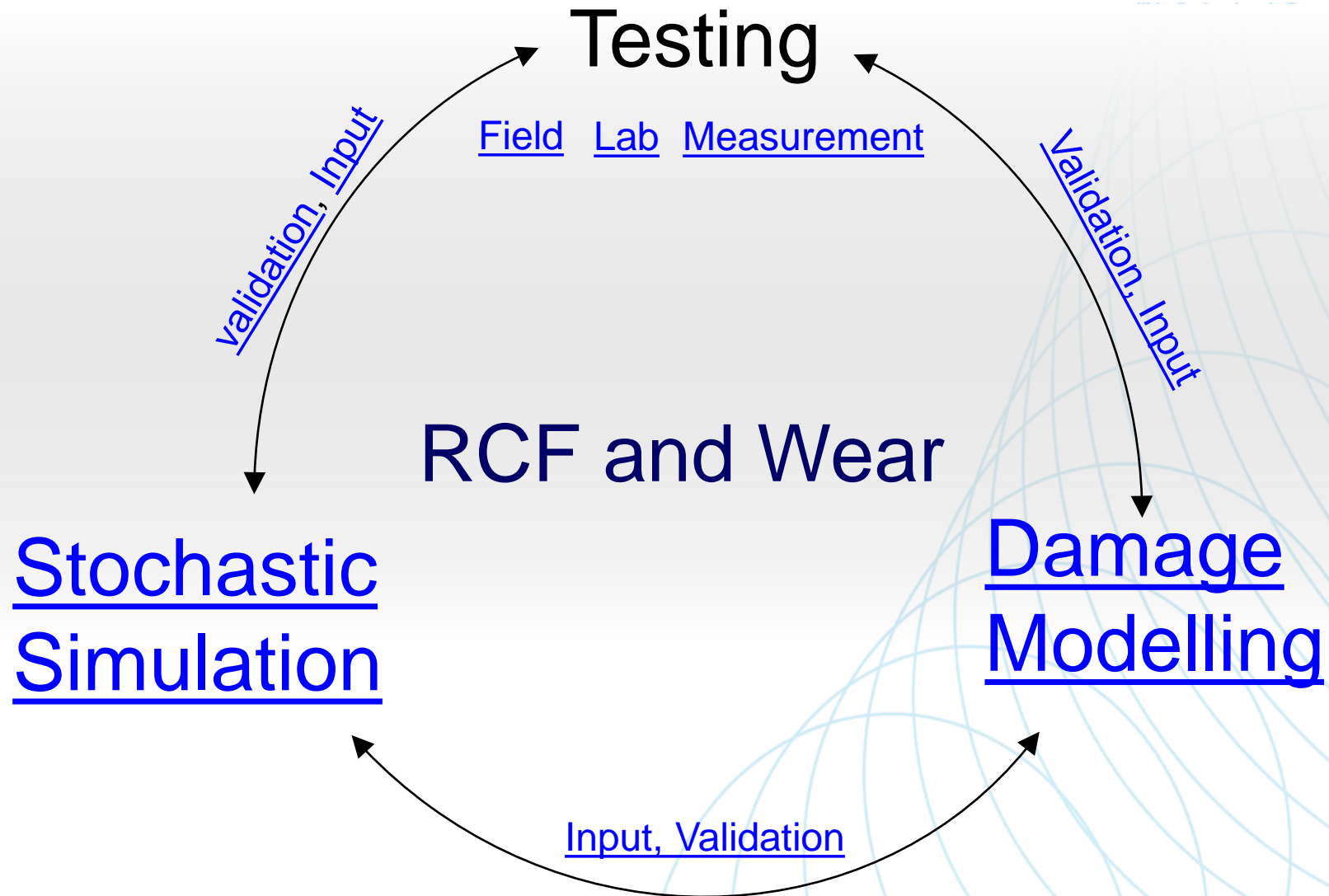
Objective

Long Term Objective: Develop predictive algorithms for rail damage and validate with North American service data.

Results of the First Phase

- Collected North American freight data on two test locations
- Stochastic modelling of the vehicle-track interactions
- Providing collaborators with the necessary modelling outputs for application into their own rail surface damage models and also providing the relevant data for validation against field observations

Vehicle/Track Interaction, RCF and Wear



Stochastic Simulation

- Simulate real-world behavior by using a large number of simulation runs with input parameters randomly selected from distributions based on real-world observations.
- Track and vehicle conditions, such as wheel/rail profiles, friction, car type, load, worn conditions of various truck components, track geometry and track stiffness, can vary greatly.
- 18 parameter with 5 changes lead to a matrix of 4 trillion cases.
- Stochastic vehicle/track models were developed and validated with measured data from instrumented wheelsets (IWS) and wayside measurement systems.
- Thousands of simulations were conducted with stochastic inputs that represent vastly varied vehicle/track conditions that exist in service.



Field Test

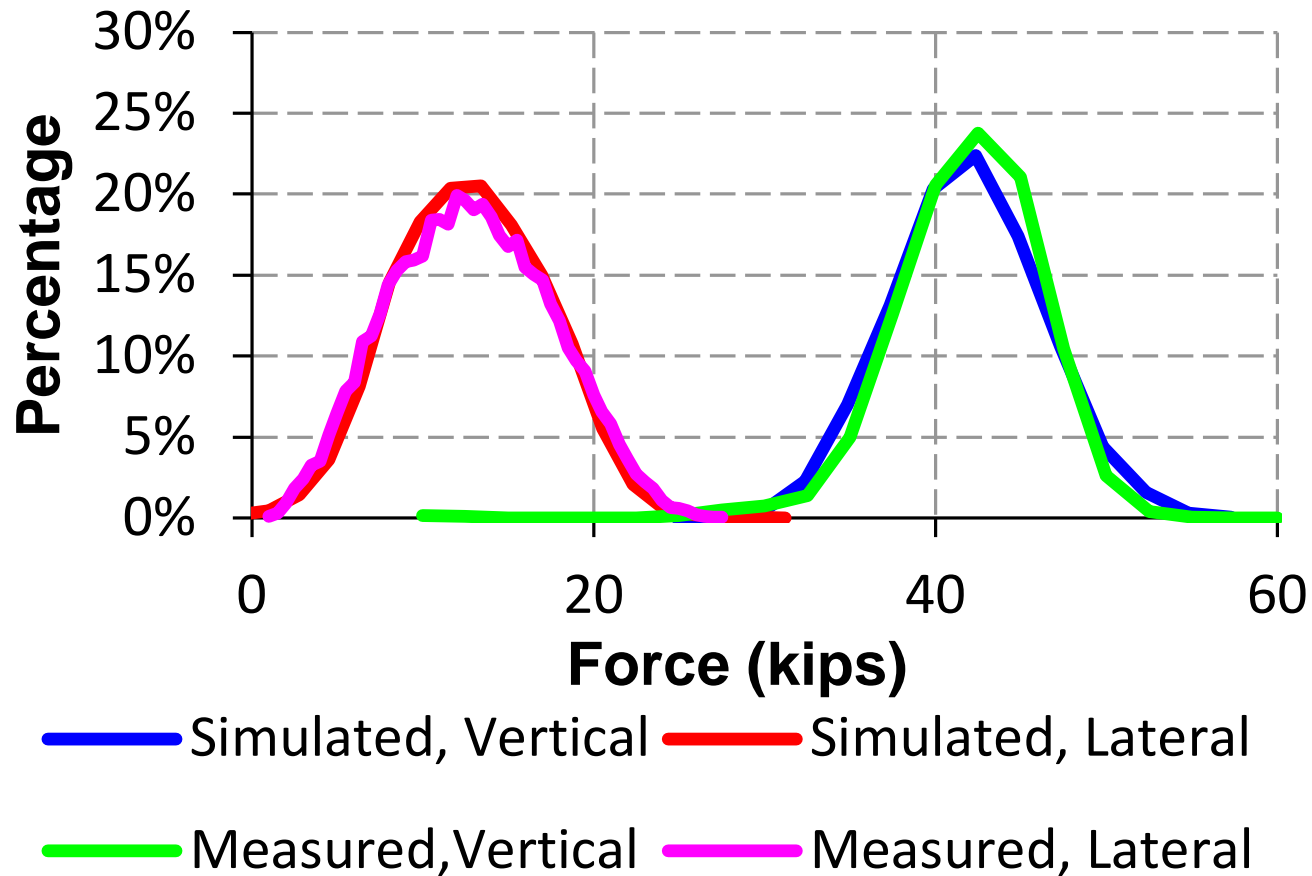


Tank car and flat car model validation

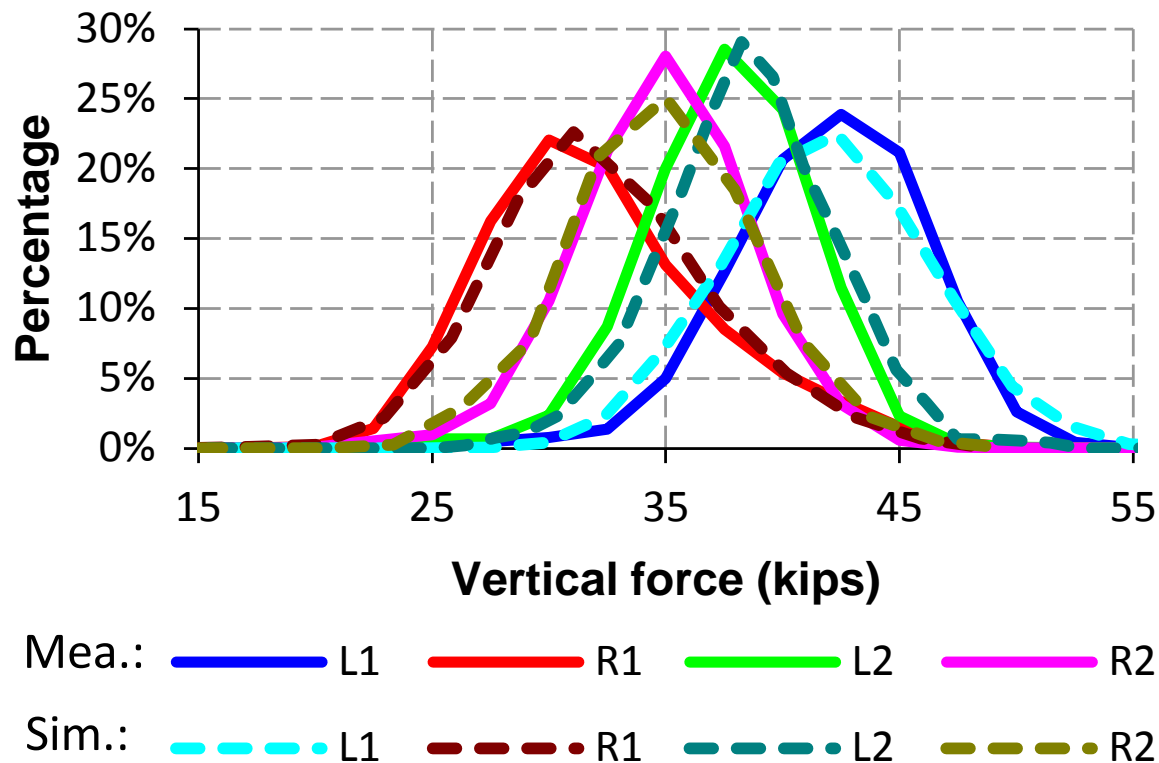


Hopper car model validation

Histogram of Vertical and Lateral Wheel/Rail Forces



Histogram of Vertical Wheel/Rail Forces



Stochastic Approach – Vehicle Side

- Hopper, tank and flat cars constitute the majority of traffic through the curves
- Created vehicle models of these car types with a variable suspension system to simulate different states of wear
- Train speed distribution obtained from nearby sensor
- Each car type has a selection of 600 measured wheel profiles (300 axles)



Vehicle Worn Conditions

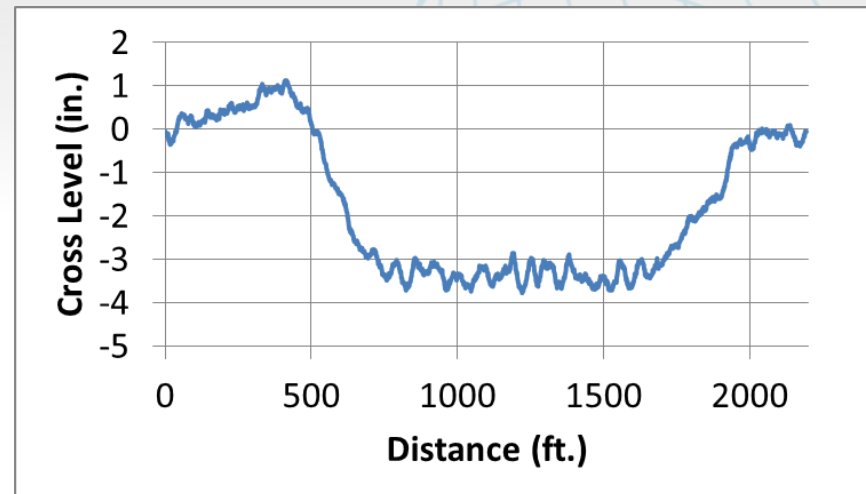
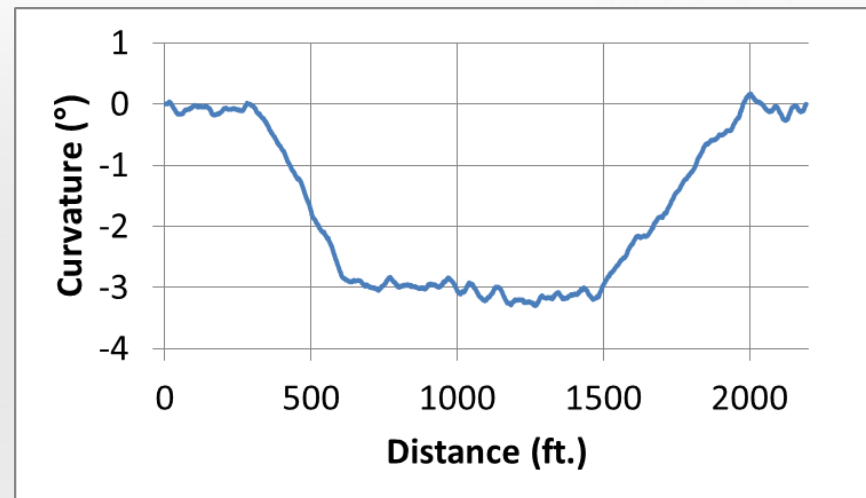
- Center place gap
- Side bearing preload
- Control spring free height
- Wedge yaw stiffness
- Adapter shear stiffness
- Different friction coefficients for various truck components



Stochastic Approach – Track Side

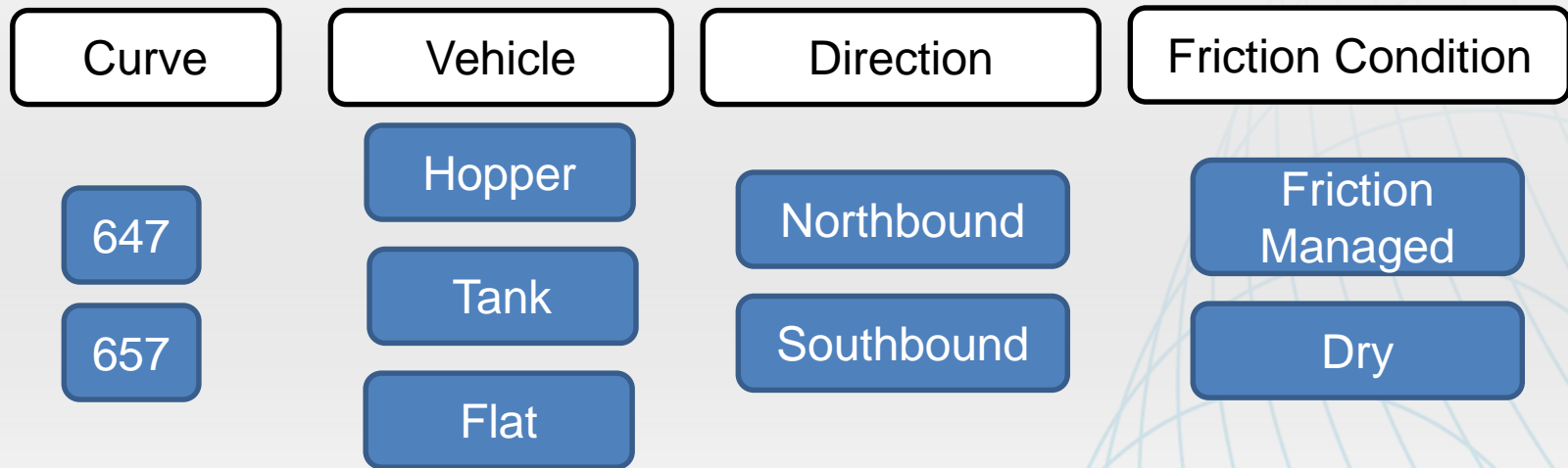
- Space-curve track geometry measured every foot
- Rail profiles measured every 5 feet
- Curves were simulated with friction-managed and dry conditions
- Friction coefficient distribution based on NRC's past experience

Curve 647 track geometry



Stochastic Approach – The Simulation

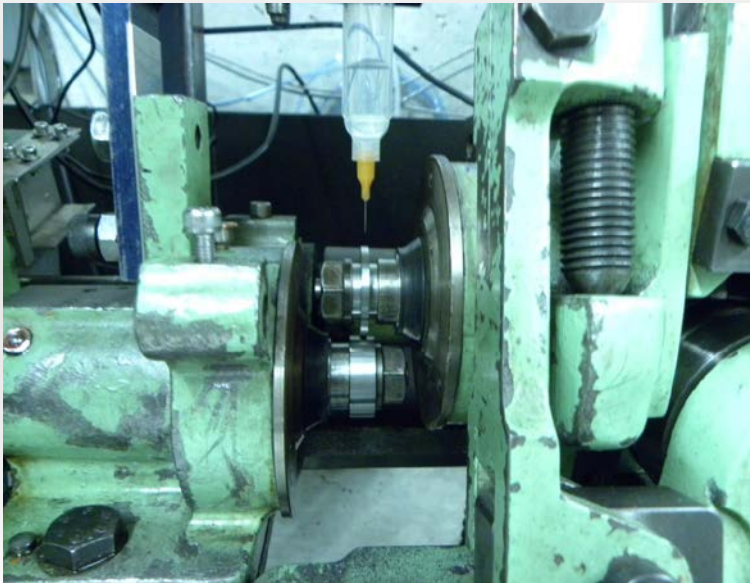
- Performed 1000 simulation runs for each condition



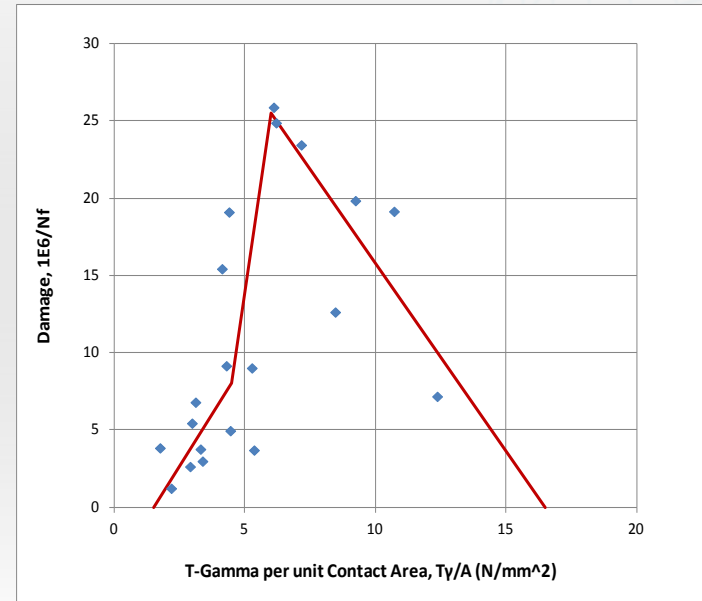
- 24,000 simulation runs, each with stochastically selected parameters:
 - Vehicle speed
 - Vehicle weight
 - Wheel profiles
 - Friction coefficient
 - Suspension characteristics



Lab Test



AMSLER Test Machine



Damage Function for a North American Premium Rail Steel
Nf – Number of cycle per failure



Field Test Locations

- Input data collected from two curves on the same track in the USA
- Mixed freight, bi-directional traffic, friction managed, regular grinding



Curve 647 is a 3° curve



Curve 657 is a 6° curve

Satellite photographs courtesy of Google Maps



Field Measurement

- Rail profiles measured every 5 feet using an optical system on board a hy-rail vehicle
- Wheel profiles measured on various types of cars
- Rail friction coefficients obtained with tribometer measurements
- MRX rail surface crack measurements
- Rail photos taken along the track

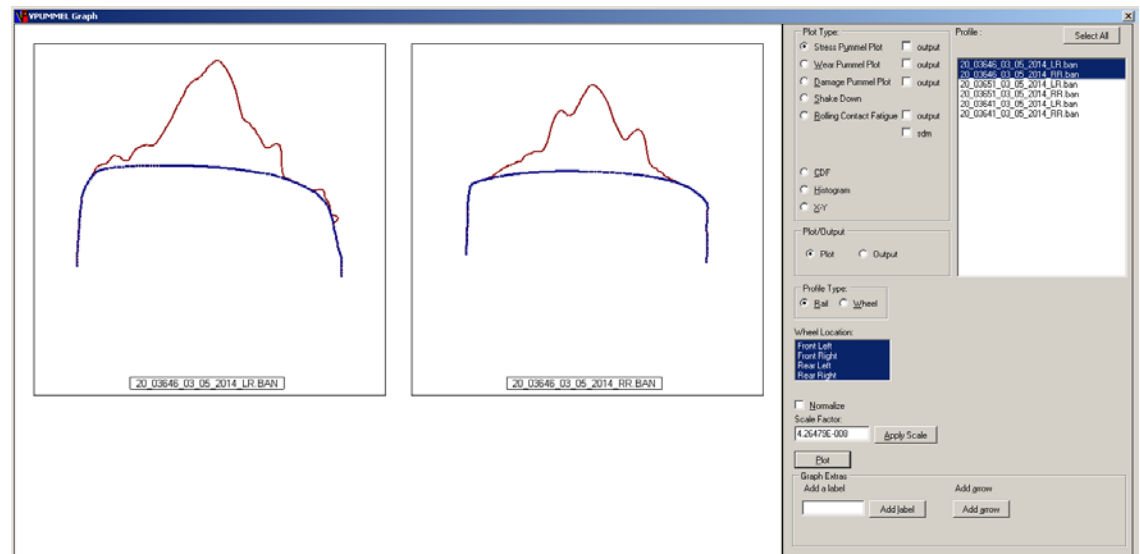


Pummelling Analysis

Dynamics simulation results

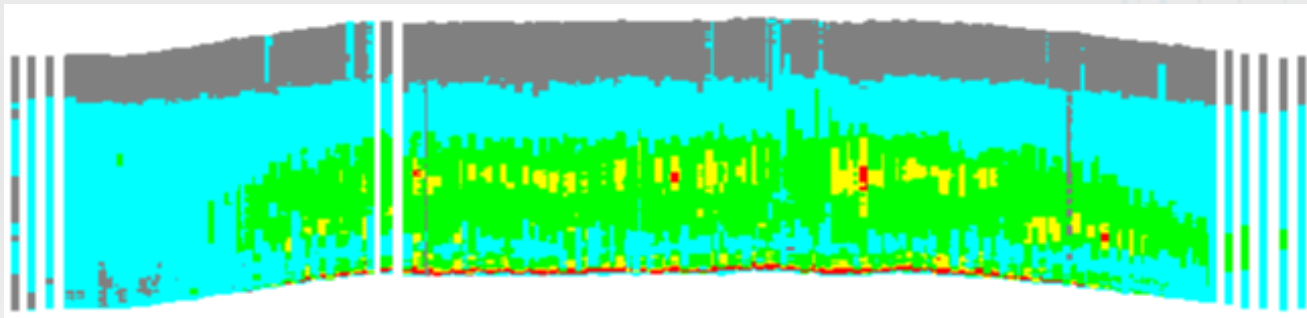
- Wheel and rail positions
- Contact patch shapes and positions
- Contact stresses
- Creepages
- Creep forces
- T_y

Pummelling – method used to represent the location, intensity and frequency of wheel/rail contact characteristics obtained through real-world testing or simulation.

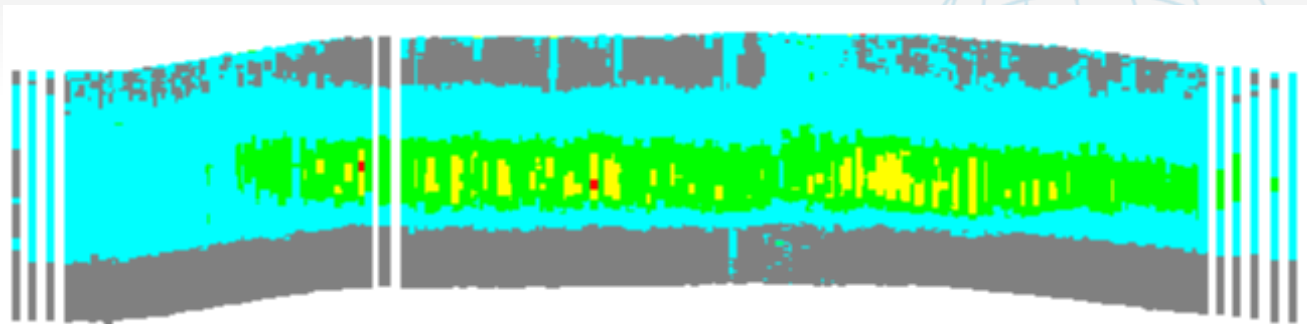


Pummelling – Preliminary Results

- Pummelling analysis of the stochastic simulation is ongoing

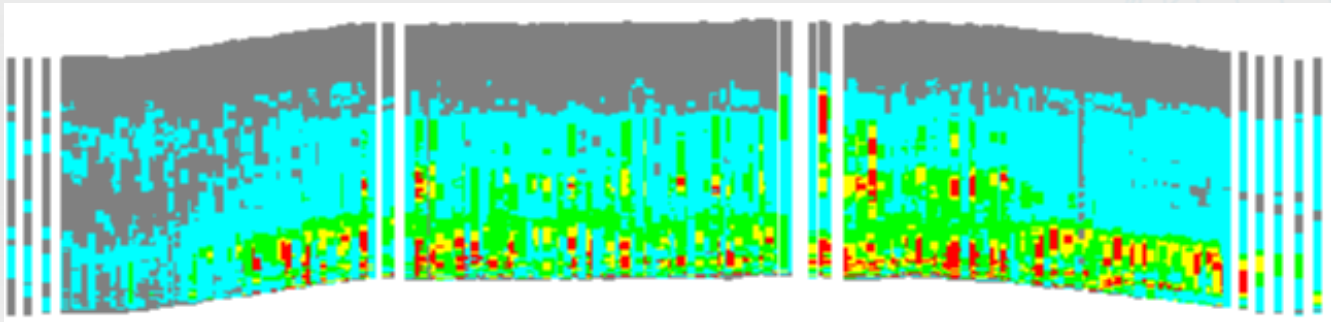


Curve 647 – friction managed – frictional work pummelling

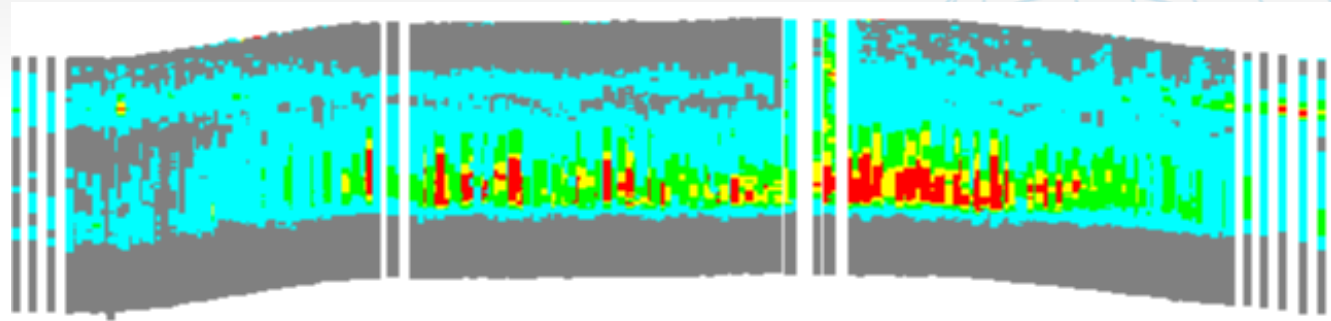


Pummelling – Preliminary Results

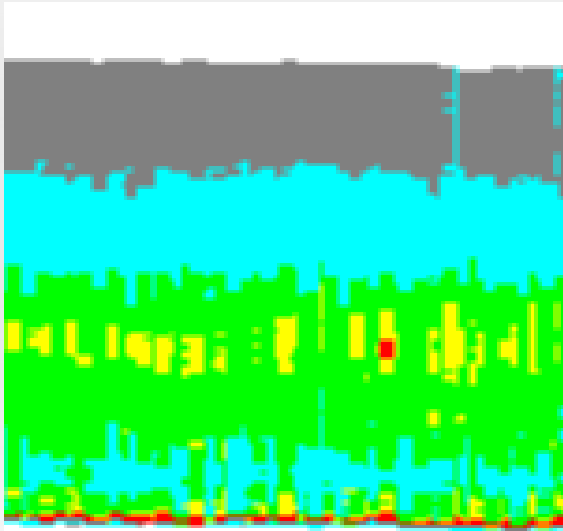
- Pummelling analysis of the stochastic simulation is ongoing



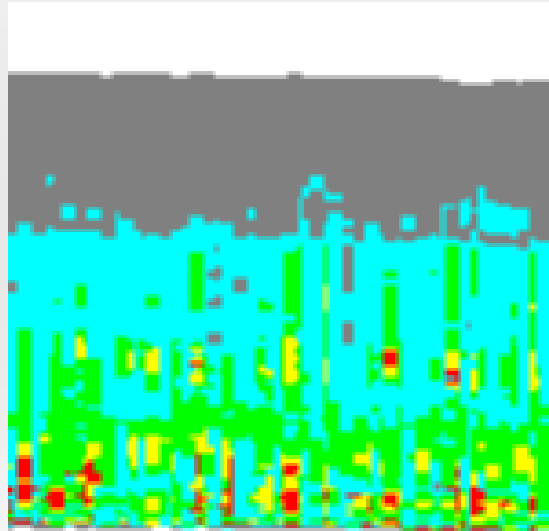
Curve 647 – friction managed – RCF index pummelling



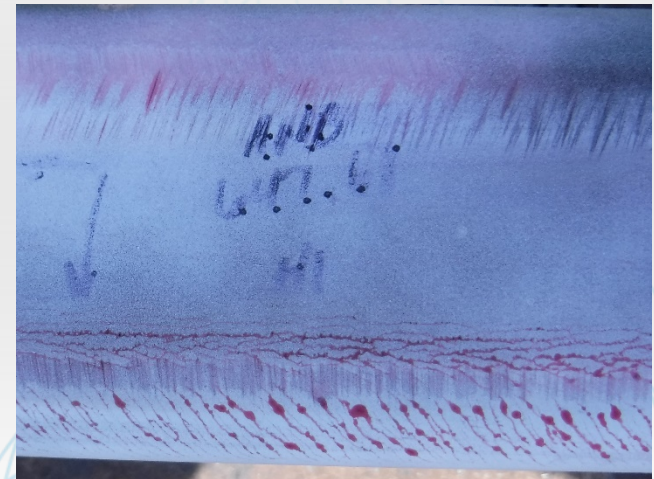
Pummelling – Validation by Photographs



Frictional Work Heat Map



RCF Index Heat Map



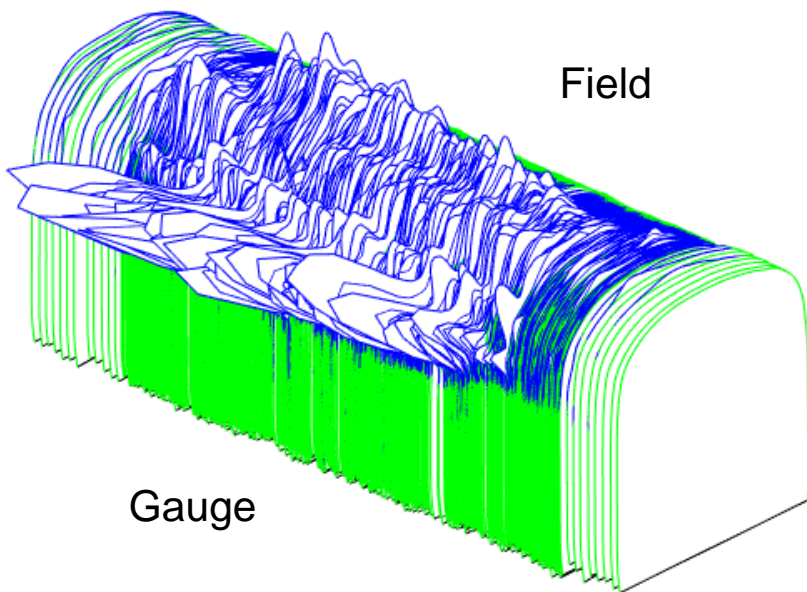
Photograph



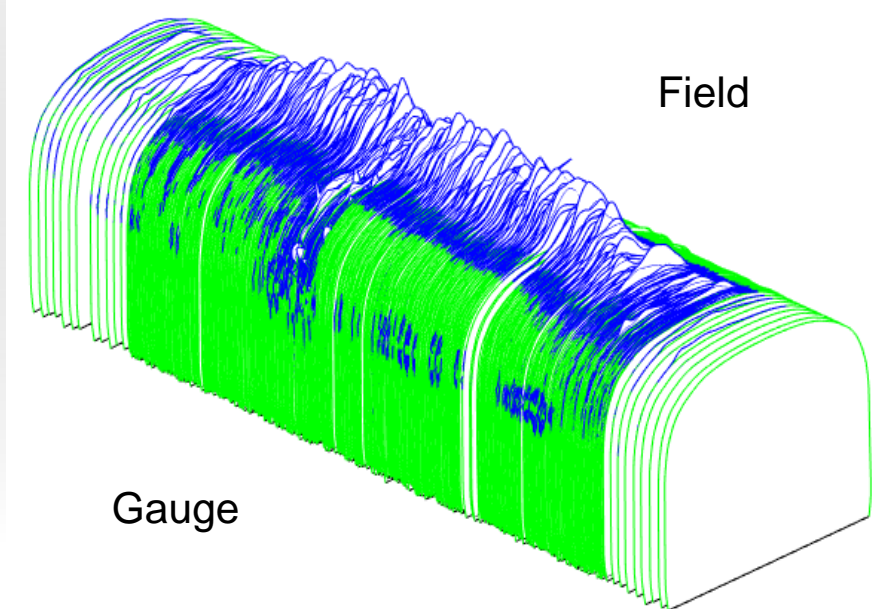
Pummelling – 3D Plots

3-dimensional plotting of the pummelling envelopes.

Curve 647 – friction managed – Frictional work pummelling envelopes



High Rail

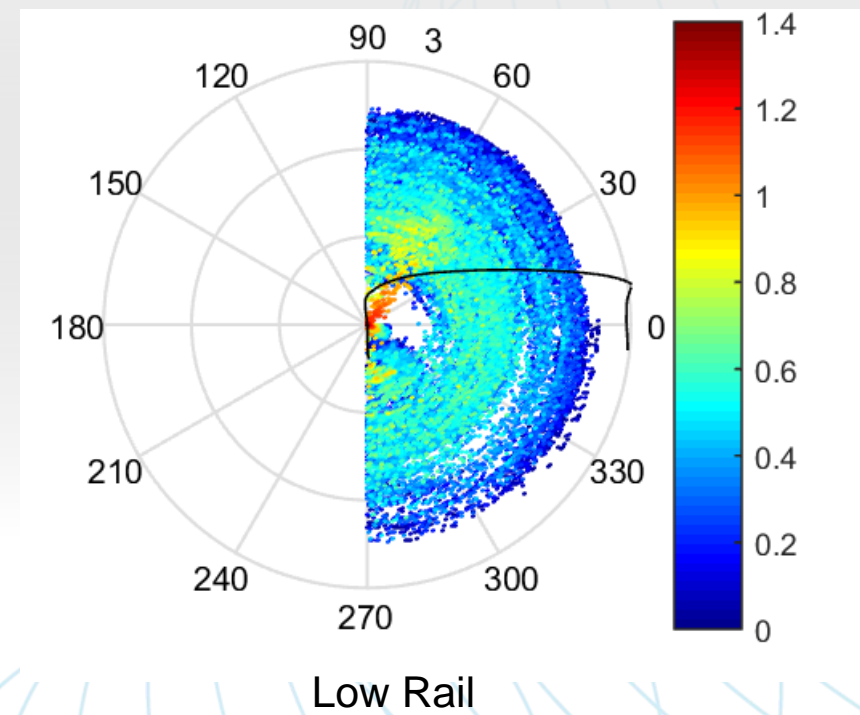
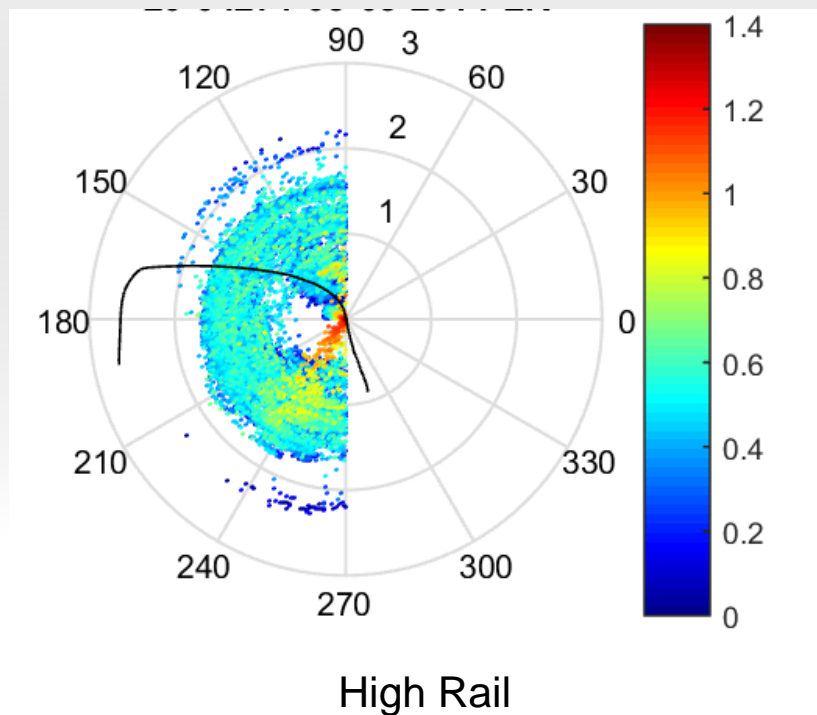


Low Rail



Pummelling – Polar Plots

- Plots showing the predicted orientation of cracks based on stochastic simulation results from previous tests



Pummelling – Next Steps

- Complete pummelling calculations for all current simulation results
- Investigate correlation between RCF index pummelling and MRX measurements
- Compare heat maps of RCF index and frictional work with rail surface photographs
- Compare heat maps for different wheel/rail contact characteristics for both curves and friction conditions
- Explore other analysis options to display pummelling results
- Keep improving the software for faster and more user-friendly processing



ICRI Data Package – Files in the Package

- The ICRI Data Package will soon be available for download from a secure FTP site
- In the package:
 - Simulation output files
 - Simulation input file
 - Track geometry
 - Rail profiles
 - Wheel profiles
 - Rail surface photographs
 - MRX files



Thank you

Wei Huang

Tel: 01-613-949-0069

Wei.huang@nrc-cnrc.gc.ca

Alexandre Woelfle

Tel: 01-613-998-9384

Alexandre.woelfle@nrc-cnrc.gc.ca

Alok Jahagirdar

Tel: 01-613-990-6997

Alok.jahagirdar@nrc-cnrc.gc.ca

