Noise Control on Light & Heavy Rail Transit Systems

Top-of-Rail Friction Control
Gauge Corner & Restraining Rail Lubrication

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LBFoster® WRI 2022

About Me

- Bachelor of Engineering Physics & Professional Engineer
- Director, Squamish Off-Road Cycling Association
- Enjoy spending time outside & with my three nieces

Outline

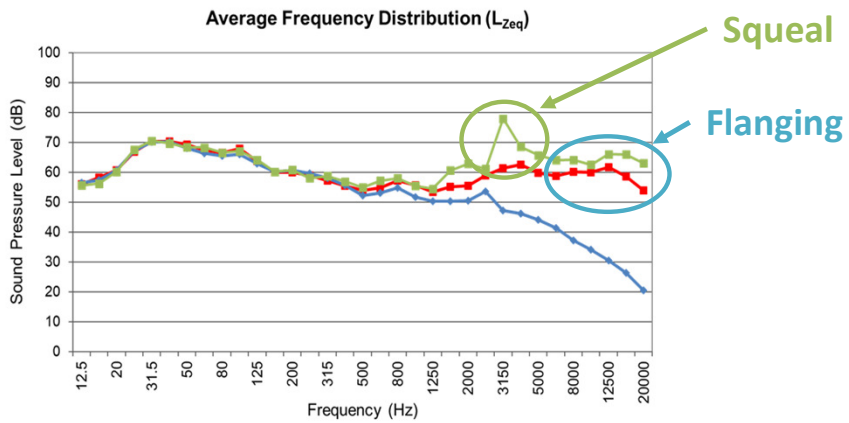
- Principles of Noise
- Recent Work – Light Rail & Heavy Rail
- New Developments – Heavy Rail
- Future Opportunities
- An Improved Understanding of Noise
- State of Good Repair

PRINCIPLES OF NOISE

Principles of Noise – Why Control It?

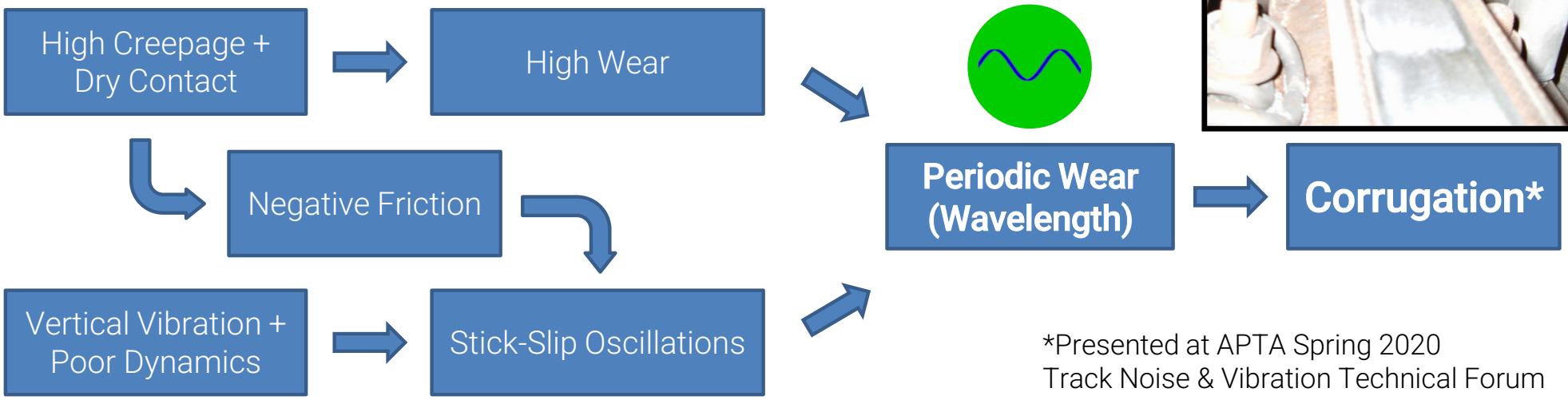
- High noise levels are harmful to health
- Transit agencies want to be good neighbours
- Measures to reduce noise also improve track condition:
  - *Better ride quality and comfort*
  - *Increased asset life*
    (rail, track components, wheels, vehicles)
  - *Reduced maintenance requirements*
    (track & vehicle)

Principles of Noise – Types

Noise Type	*Frequency Range, Hz*	*Characteristics*
Rolling / Roughness (e.g. Corrugation)	30 -2500	
Rumble	200 - 1000	
Flat spots	50 -250	
Ground Borne Vibrations	30 - 200	
Squeal (tonal)	1000 - 5000	> High pitched, tonal squeal. > Prevalent in curves usually < 350 meter radius (5 deg). > Typically a well-defined frequency peak.
Flanging (hissing)	5000 – 10000	> A "buzzing" or "hissing" sound. > Typically high-frequency and broadband.

Principles of Noise - Corrugation

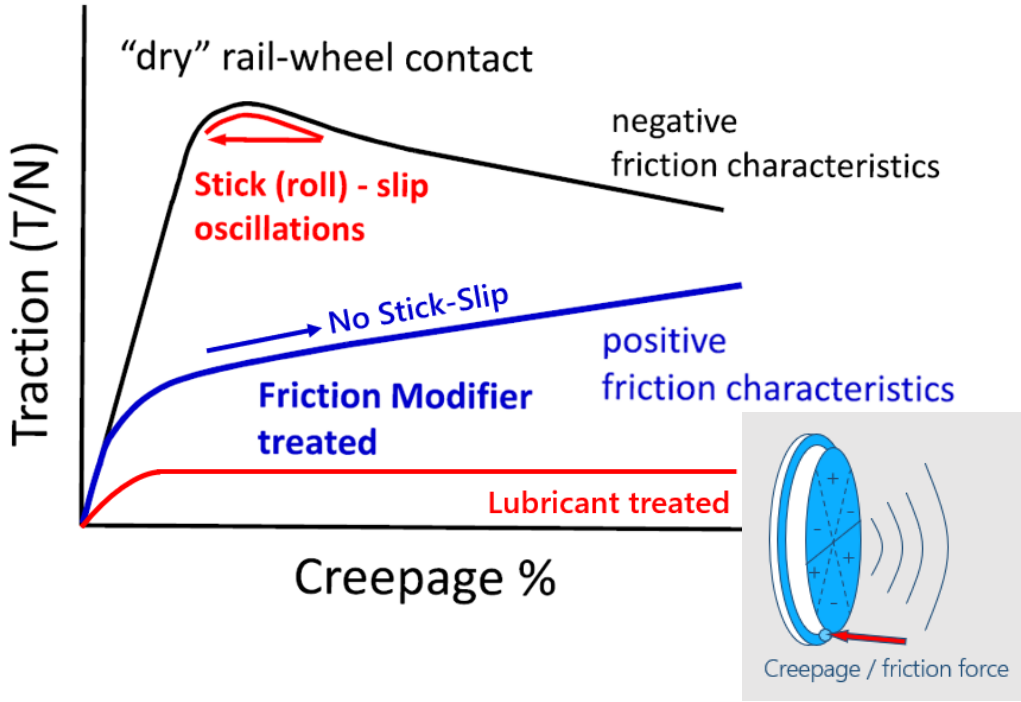
- Corrugation is common in sharp curves
- Reducing corrugation growth rates can dramatically reduce noise & grinding requirements



*Presented at APTA Spring 2020
Track Noise & Vibration Technical Forum

Principles of Noise - Squeal

- Squeal noise is common in sharp curves
- Negative friction conditions lead to stick-slip oscillations
- Stick-slip oscillations cause the wheel to vibrate, like a speaker
- Positive friction from a Friction Modifier alleviates stick-slip



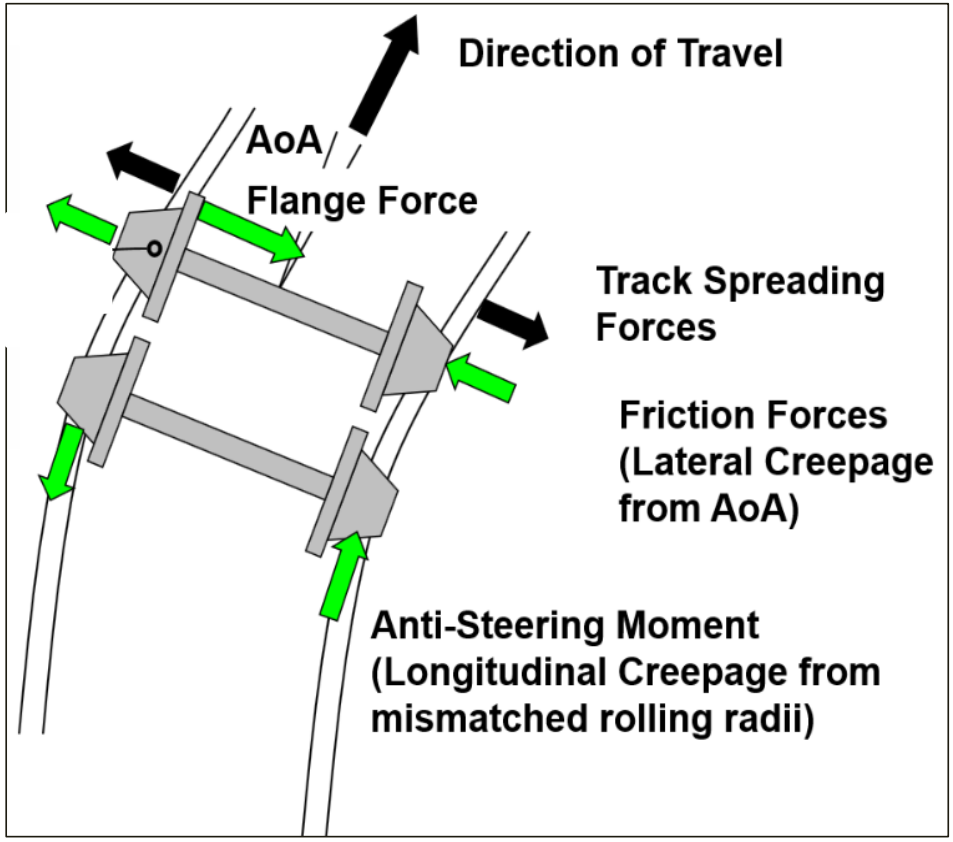
R. Stock, L. Stanlake, C. Hardwick, M. Yu, D. Eadie and R. Lewis, Material Concepts for Top of Rail Friction Management - Classification, Characterization and Application, Wear, vols. 366-367, pp. 225-232, 2016.

Principles of Noise - Flanging

- Flanging is common in sharp curves

Sharp Curve & Insufficient Rolling Radius Difference → Large Angle of Attack & Flanging

- Can occur on:
  - High rail (most common)
  - Restraining rail (if present)
  - Low rail (extreme case)
- Controlling top-of-rail friction reduces flanging force & noise



RECENT WORK – LIGHT RAIL

Recent Work – Light Rail

- SkyTrain in Vancouver, Canada commissioned a noise study in 2018 in response to noise concerns raised by residents.
- The study meticulously measured corrugation (rail roughness) over three (3) years to control for seasonal environmental factors.
- Baseline corrugation was present in both curved *and tangent* track.
  - Radius **450m (1500ft)**; Annual Tonnage **18 MGT**; Track Speed **80 kph (50 mph)**
- Historically, grinding was being conducted every 3 months to keep noise increases below 10dB.

Results are publicly available at:
https://www.translink.ca/plans-and-projects/projects/maintenance-and-upgrade-program/rail-projects

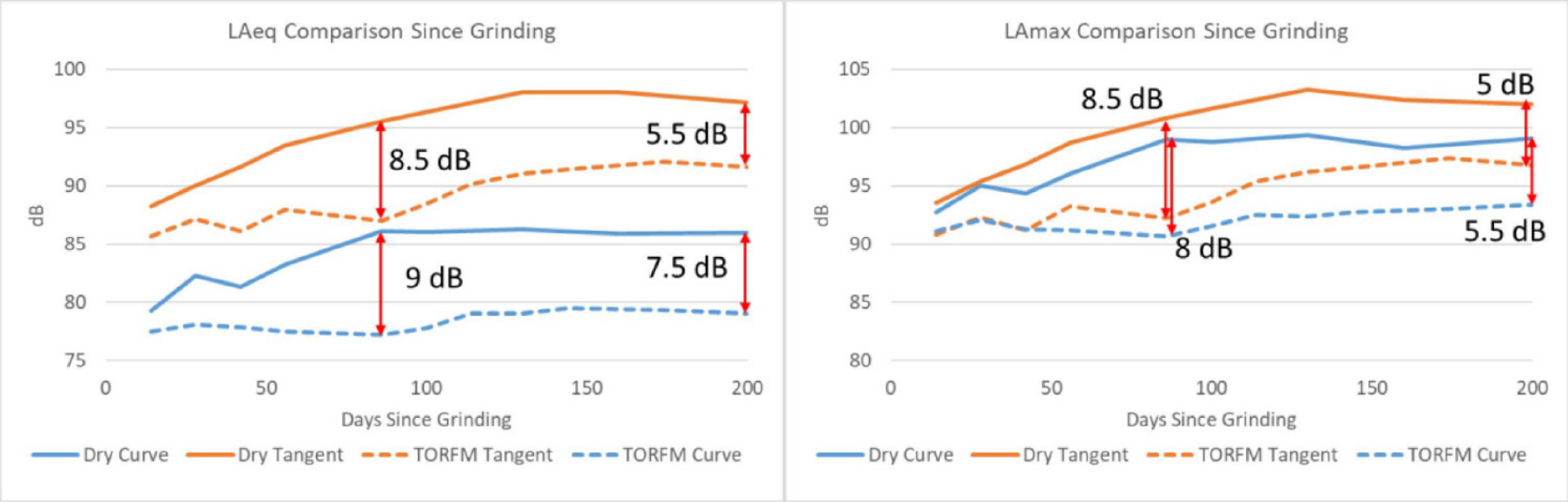
Recent Work – Light Rail

- Water-based top-of-rail friction modifier (KELTRACK®) was applied for 6 months

Results are publicly available at:
https://www.translink.ca/plans-and-projects/projects/maintenance-and-upgrade-program/rail-projects

Recent Work – Light Rail

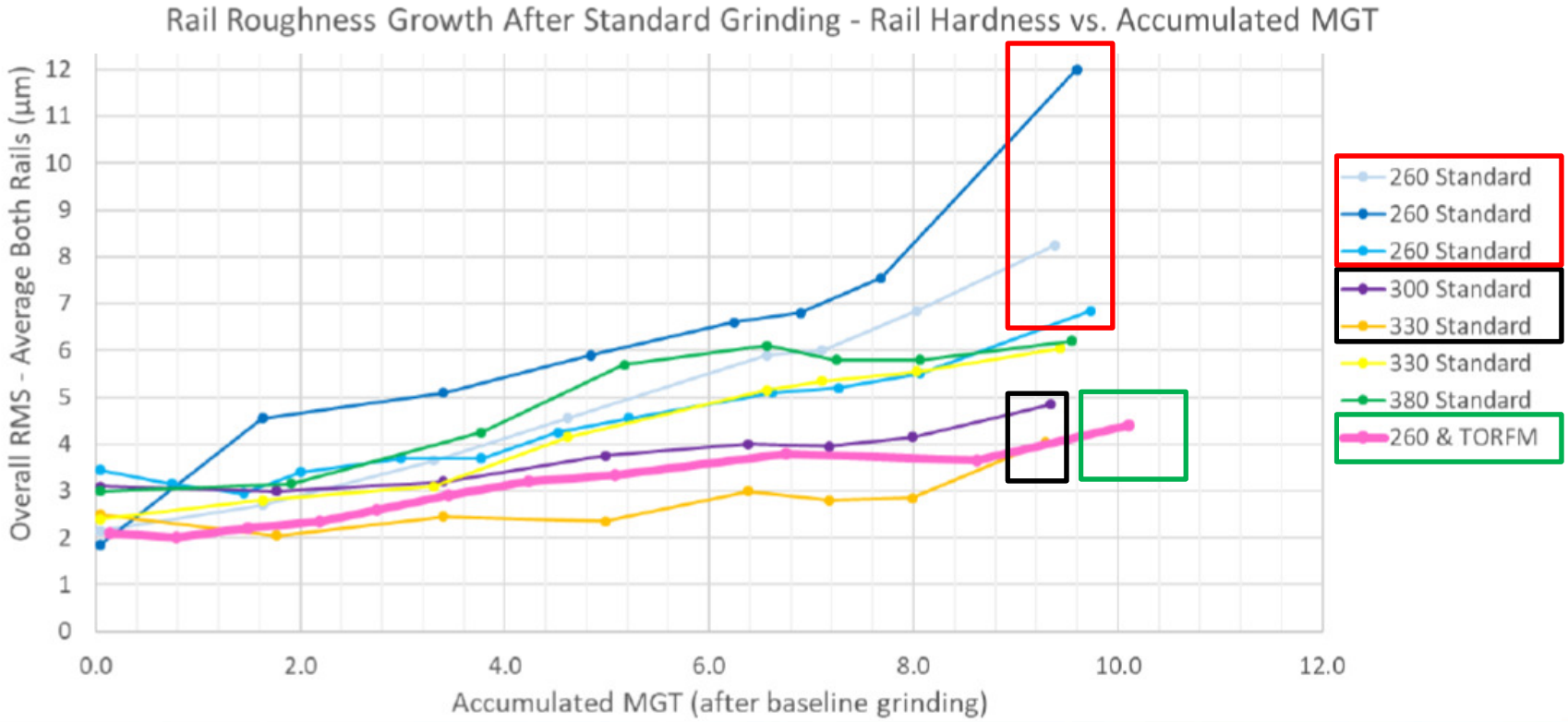
> The study concluded that the friction modifier was able to reduce the noise increase over 3 months by 8-9dB, and over 6 months by 5-7dB.



> This creates substantial opportunities to save money on grinding

Recent Work – Light Rail

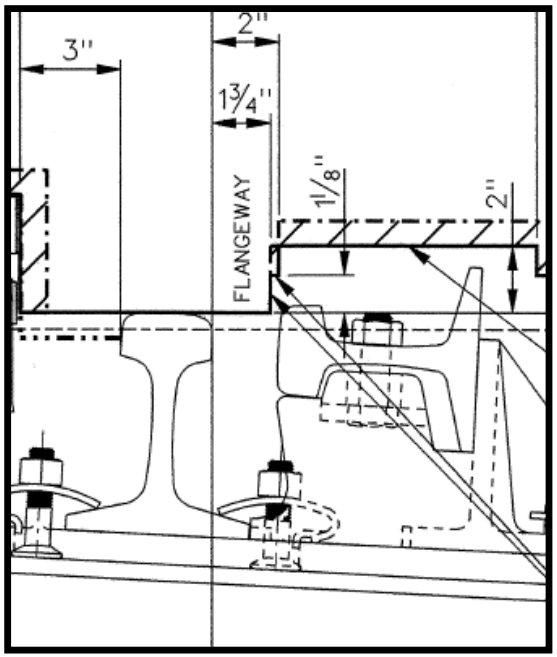
> The study also showed that the friction modifier is very effective at protecting softer rail:



RECENT WORK – HEAVY RAIL

Recent Work – Heavy Rail

- L.B. Foster asked to investigate severe noise on a North American heavy rail subway system in 2021.
- Horizontal restraining rail is used in most curves.
- The primary goals were to:
  - A) Determine the source(s) of the noise.
  - B) Identify the most effective mitigation strategy.
  - C) Better understand restraining rail noise.



Recent Work – Heavy Rail

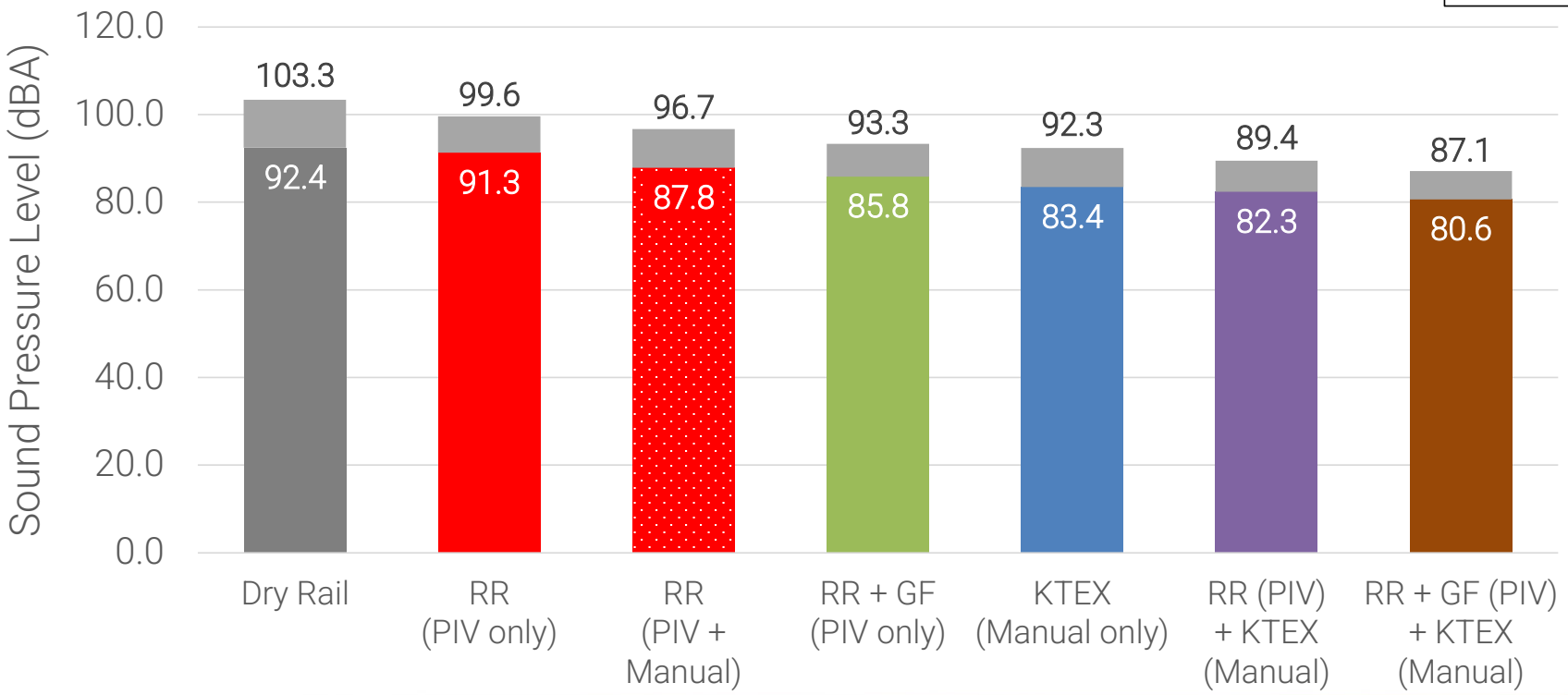
- Phase 1 testing was conducted in September 2021.*
- Noise measurements were taken under combinations of:
  - Automatic application of SYNCURVE® Transit on the high rail and restraining rail
  - Manual application of KELTRACK® Transit EX on the top-of-rail
- The following conditions were present:
  - Curve Radius **125m (412ft)**; Curve Length **210m (700ft)**
  - Work-Zone Track Speed **10 kph (6 mph)**
  - Restraining Rail with 2 inch flangeway clearance
  - Mild to moderate corrugation visible on both low and high rail
  - 2-point contact on high rail

*Presented at ICRI Workshop Ottawa 2022

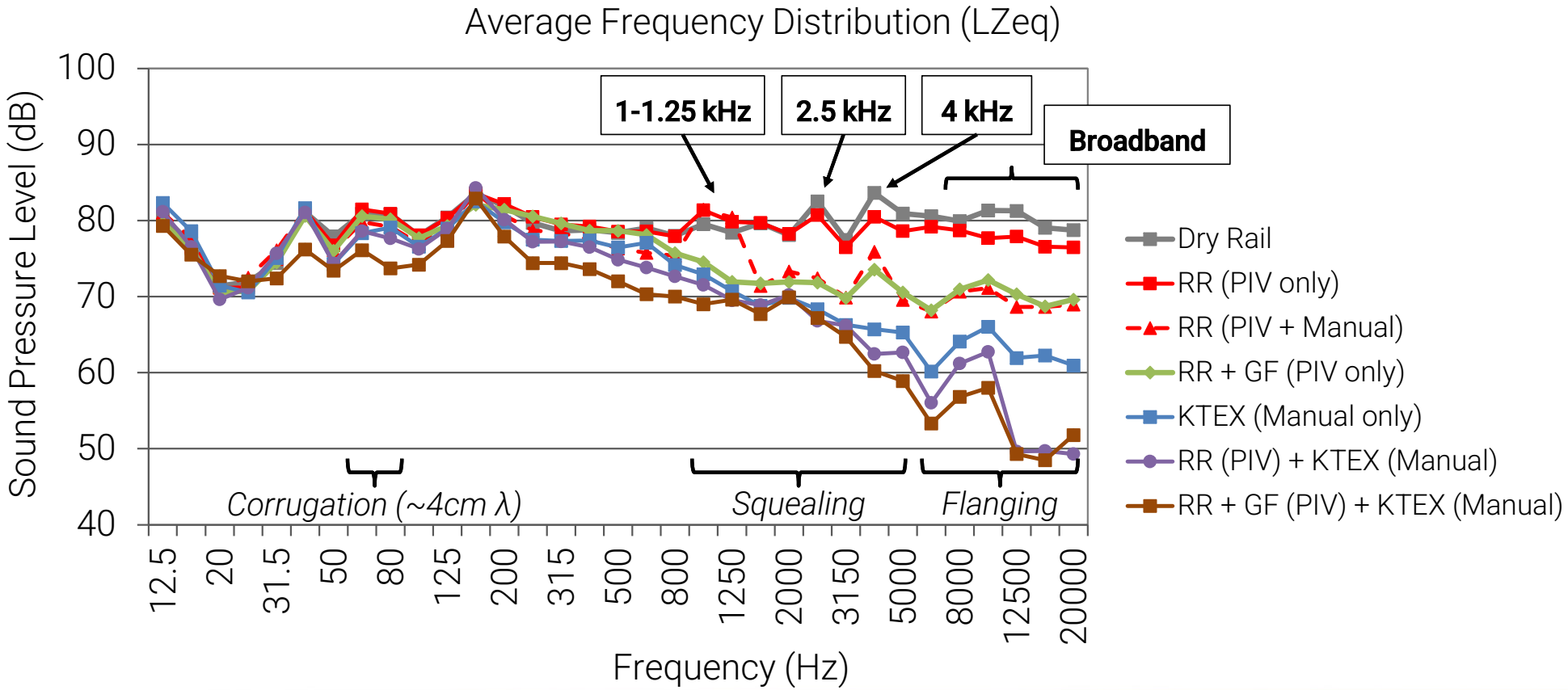
Recent Work – Heavy Rail

Average Equivalent Continuous Sound Level (LAeq)
and Max Sound Level (LAFmax)

RR: Restraining Rail
GF: Gauge Face/Corner
KTEX: KELTRACK Transit EX
PIV: PROTECTOR IV



Recent Work – Heavy Rail

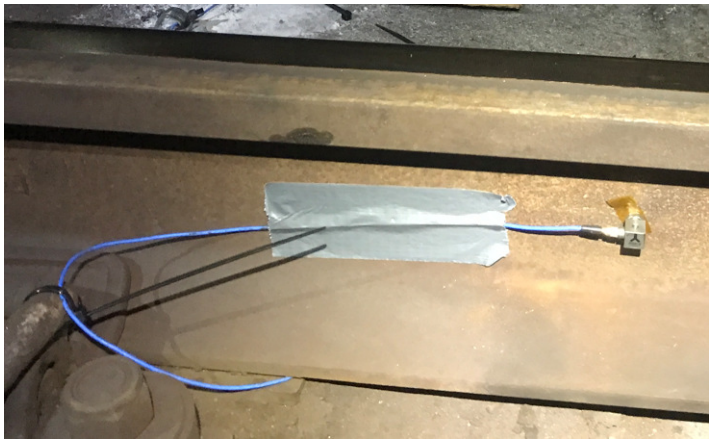


NEW DEVELOPMENTS – HEAVY RAIL

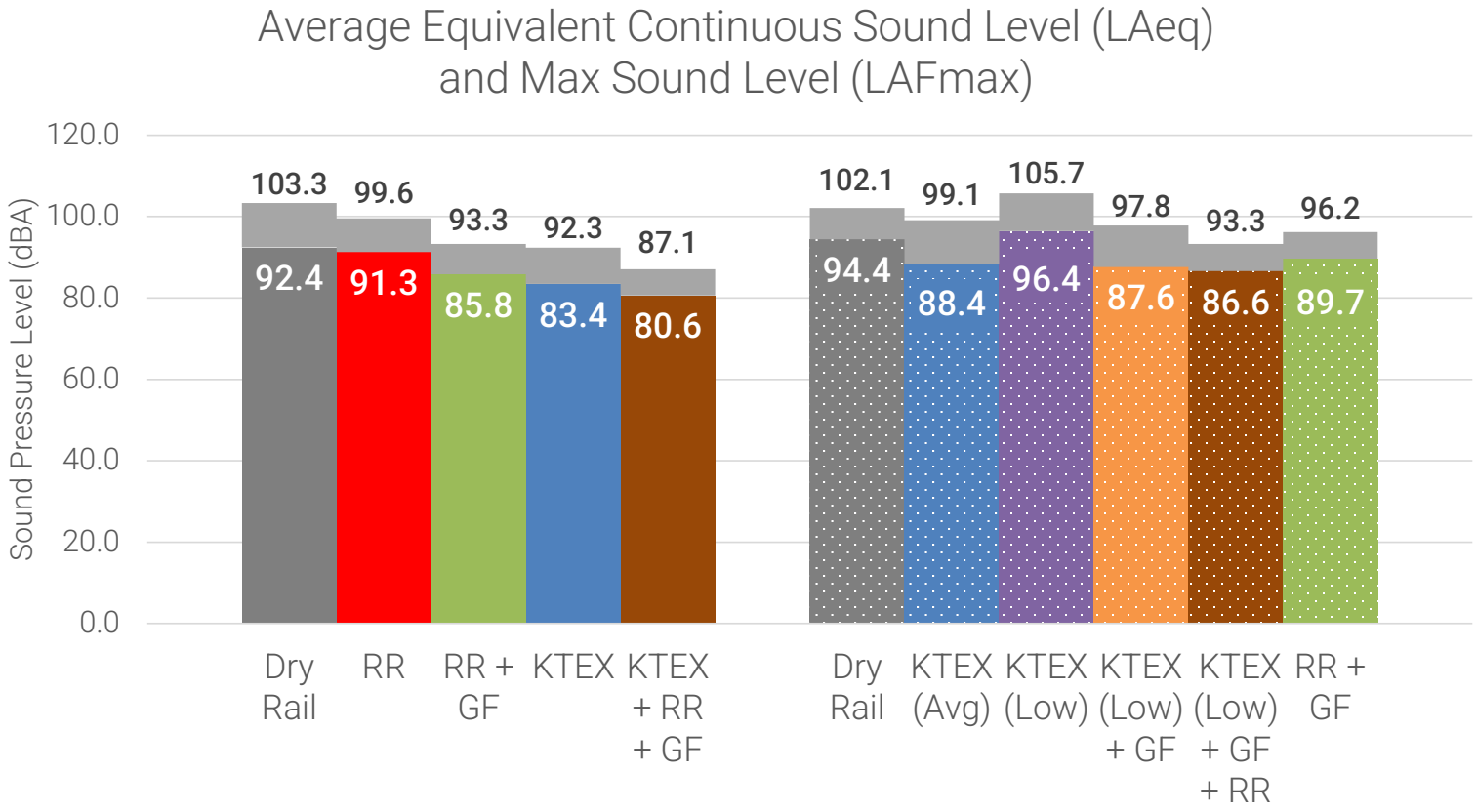
New Developments – Heavy Rail

- Phase 2 testing was conducted in June 2022.

- Notable differences from Phase 1:
  - Automatic, not manual, application of KELTRACK® water-based top-of-rail friction modifier
  - Measured vibration of all three rails
    High Rail (web), Low Rail (web), Restraining Rail (base)
  - Track conditions seemed somewhat improved vs September
    (Corrugation; 2-point Contact)



New Developments – Heavy Rail



RR: Restraining Rail

GF: Gauge Face/Corner

KTEX: KELTRACK Transit EX

Phase 1:

RR/GF PROTECTOR IV

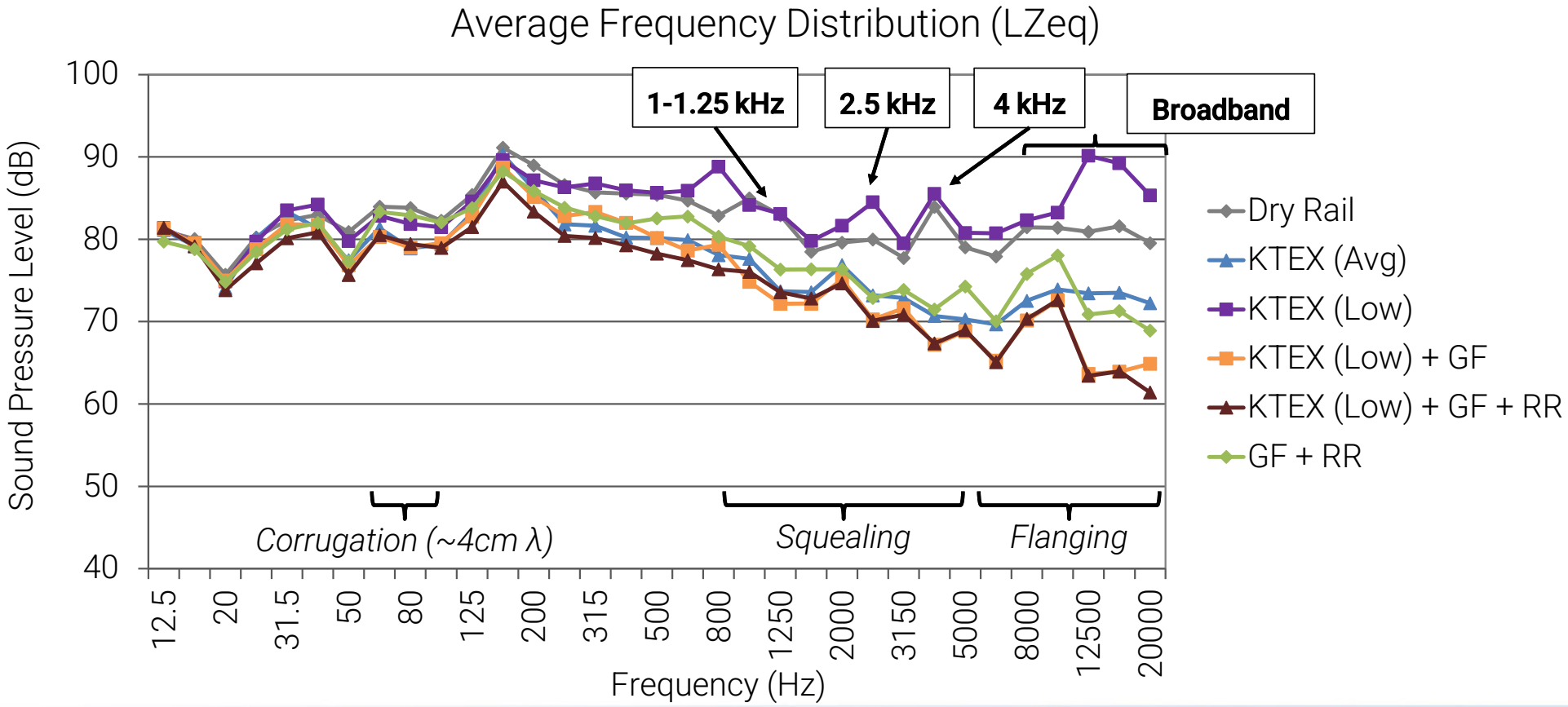
KTEX Manual

Phase 2:

RR/GF PROTECTOR IV

KTEX PROTECTOR IV

New Developments – Heavy Rail



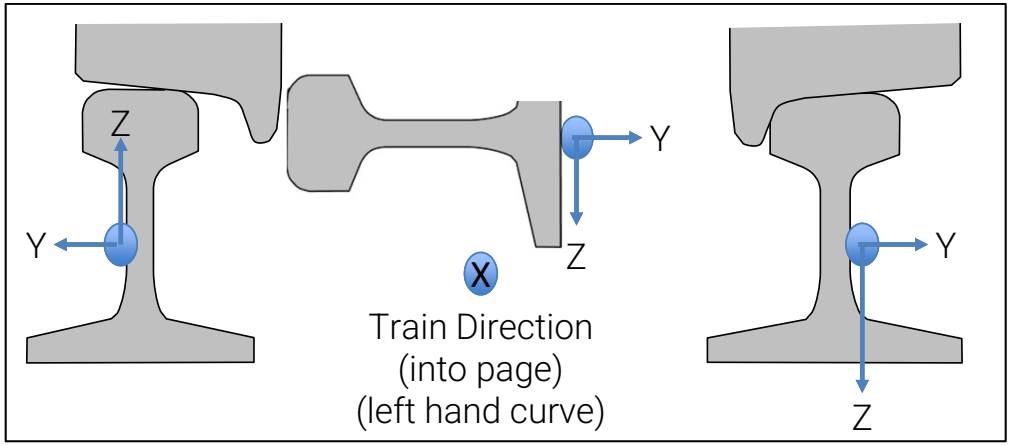
Heavy Rail Takeaways

- Phase 1:
  - The most effective solution is: ***Water-based Top-of-Rail Friction Modifier and RR/GF Grease***
    - ***12-16 dB reduction***
  - If I were to pick one product only: ***Water-based Top-of-Rail Friction Modifier***
    - ***9-11 dB reduction***
- Phase 2:
  - The most effective solution is: ***Water-based Top-of-Rail Friction Modifier and RR/GF Grease***
    - ***7-9 dB reduction***
  - If I were to pick one product only: ***RR/GF Grease***
    - ***4-6 dB reduction***
- Sometimes, conditions change.
  - Using both products in challenging areas ensures maximum noise reduction & infrastructure protection.

FUTURE OPPORTUNITIES

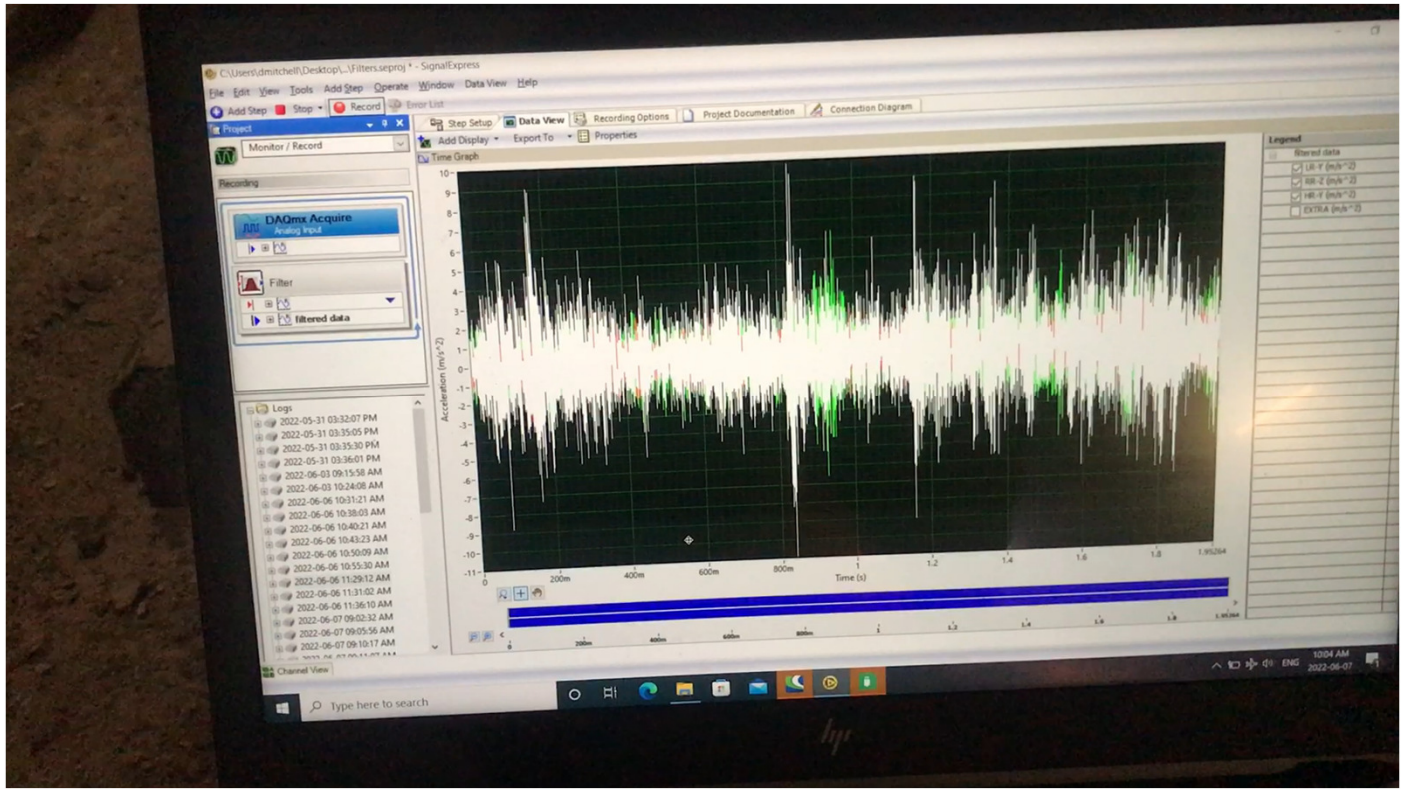
Future Opportunities

- Vibration Analysis
  - Measure vibration of all three rails
    - High Rail (web), Low Rail (web), Restraining Rail (base)
  - Sampling Rate: 10 kHz
  - Nyquist Frequency: 5 kHz
    - Maximum frequency valid for analysis – no aliasing



- Questions to investigate:
  - How much are the rails vibrating with respect to each other?
    - *Compare Root Mean Square (RMS) and Peak acceleration values*
  - What frequencies are the rails vibrating at?
    - *Look at the Power Spectral Density (PSD) – a representation of how power is distributed over frequency*
  - Can vibration analysis augment sound analysis?
    - *Aid in identification of optimal Friction Management program & solution*
  - How do conditions change between slow speed and revenue speed?

Future Opportunities



IMPROVED UNDERSTANDING OF NOISE

An Improved Understanding of Squeal Noise

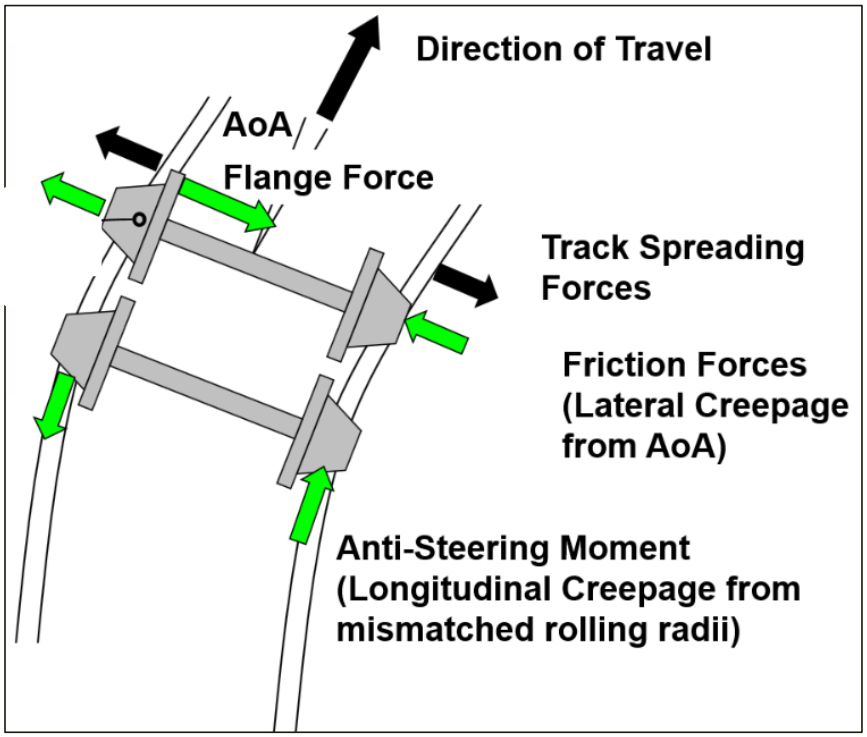
- Typically thought to originate at the top-of-rail and be addressed by water-based friction modifiers.
- In some situations (e.g. sharp curves with load-bearing restraining rail), it is clear that squeal noise can be substantially reduced using premium lubricants at the gauge face & corner.
- It would logically follow that squeal noise can originate from the gauge face/corner, as well as the top-of-rail.
- There is precedent for this thinking:
  - [1]*Hanson D, Jiang J, Dowdell D, Dwight R. Curve Squeal: Causes, Treatments and Results. Inter-noise; 2014; Melbourne, Australia.*
  - Used sound, vibration, and truck performance detection to show squeal could originate from both the top and gauge corner of both the high and low rail.
- Have to be careful, since gauge face lubrication can also exacerbate squeal noise in some situations.

A Reinforced Understanding of Flanging Noise

- Further evidence that flanging noise can be effectively reduced in two ways:

1) By application of a premium lubricant to the gauge face/corner & restraining rail
   - *Mechanism: Reduced flanging friction*

2) By application of a water-based friction modifier to the top-of-rail
   - *Mechanism: Reduced flanging force*

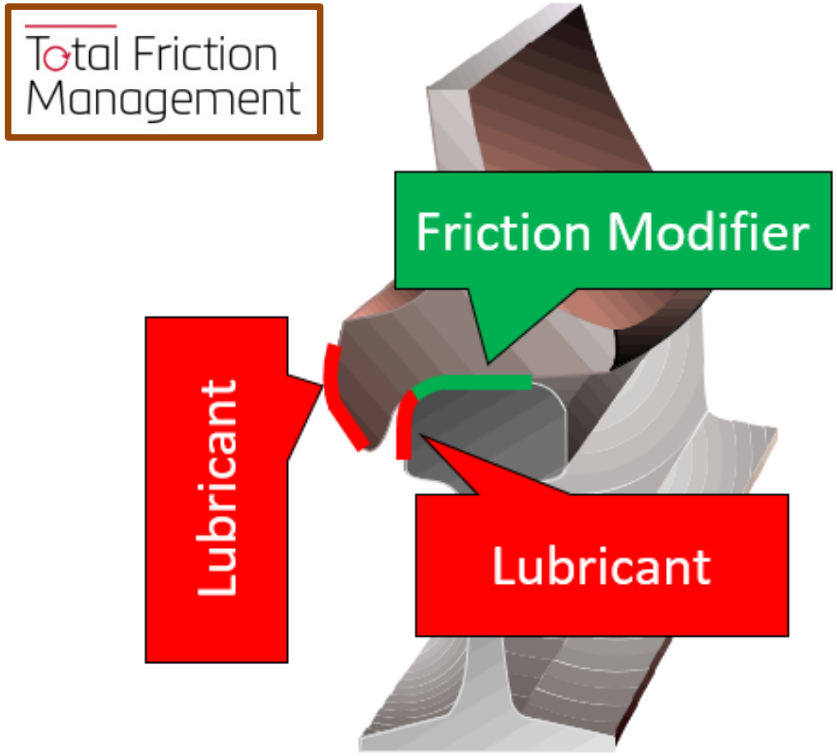


A Improved Understanding of Restraining Rail Noise

- Restraining rail contact did not appear to be a significant contributor to noise.
- However, restraining rail wear was a concern.
- Thus, lubrication of the restraining rail is recommended.

The Importance of Total Friction Management

- Sometimes, conditions change:
  - *Rail profiles & 2-point contact (grinding/milling)*
  - *Presence & magnitude of corrugation*
  - *State of restraining rail wear*
- Depending on conditions, the most effective friction management product may be different
- Regardless of conditions, Total Friction Management ensures optimal noise reduction:
  - Top-of-Rail: *Water-based friction modifier*
  - Gauge Face/Corner: *Premium lubricant*
  - Restraining Rail: *Premium lubricant*



State of Good Repair

- Friction Management does not just reduce noise
- Noise is a good indicator of track condition
- Rail and Wheel life extension are substantial (2 to 3x)
  - Reduced wear rates
  - Reduced grinding requirements (frequency and/or depth/passes)
- Track components last longer (fasteners, clips, joints, etc)

Thank You

Acknowledgements

Questions?