Optimizing Maintenance and Wheel Rail Surface Roughness to Reduce Light Rail Train Noise

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Background

- Sound Transit Link Light Rail in Seattle
- Rolling stock is semi-low floor articulated LRVs, disk braked with resilient wheels, max speed 55 mph (~90 kph)
- Direct fix slab track on elevated guideway and in tunnels
- Embedded or ballasted surface track at grade
- 115RE rail, relatively hard – 320HB or more is standard, sections of 370+ HB premium high strength rail
- Harder rail steels influence long term noise outcomes since maintenance relies on available traditional grinding equipment optimized for rail reprofiling rather than acoustic roughness

Genesis of the project

- Between 2013 and 2017, noise emissions were around 2 dB higher than the FTA Manual
- Concern noise impacts from existing tracks and new extensions may exceed predictions and guideline levels
- Excessive noise attributed to rail surface condition
- Variability in roughness and noise between different sites
  - e.g. one test site exhibited rolling noise 4 dB lower than other sites
- Corrugation a factor in some areas

Sound Transit responded by developing a new rail grinding and polishing strategy, trialed in 2018 and implemented from 2019

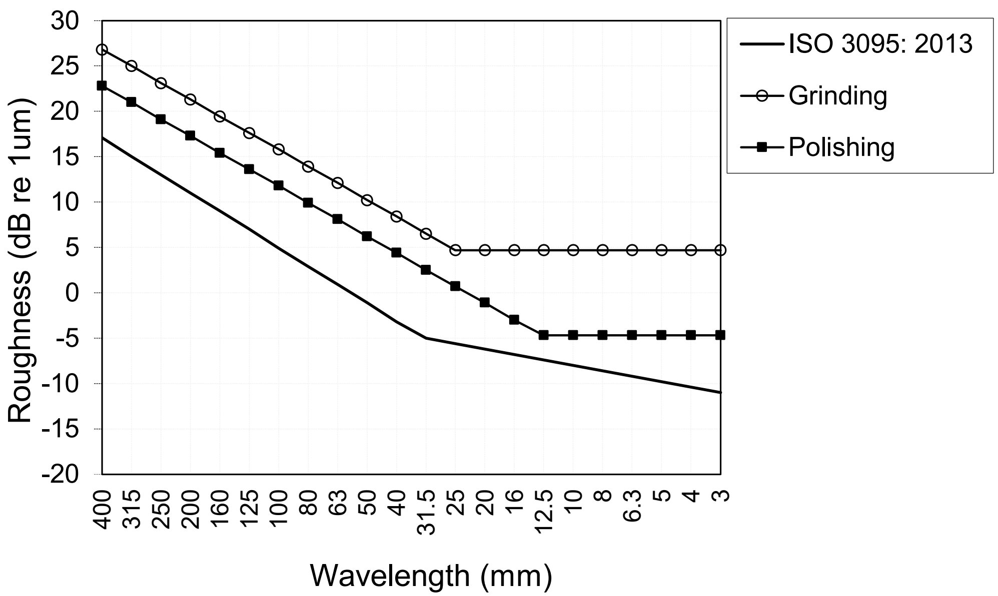
Top left: In 2016 approximately 5 miles (8 km) of track entered revenue service after rail target profile installation left coarse residual grind marks. This image is the grind signature still present 2 years after coarse grind.

Top middle: after grinding with medium grit stones.

Top right: after acoustic polishing step.

Improved rail grinding specifications

New specifications were derived and tested within the constraints of existing available equipment, ultimately leading to a 2-step grinding and polishing procedure



- First for North America
- Higher "grinding" limit for reprofiling / higher metal removal grinding
- "Polishing" as second step targeting smoother rails, residual grinding signature shifted from 32.5mm wavelength band to 50mm

Grinding trials

Sound Transit allocated budget and track time to trial different approaches with medium and fine grit stones:

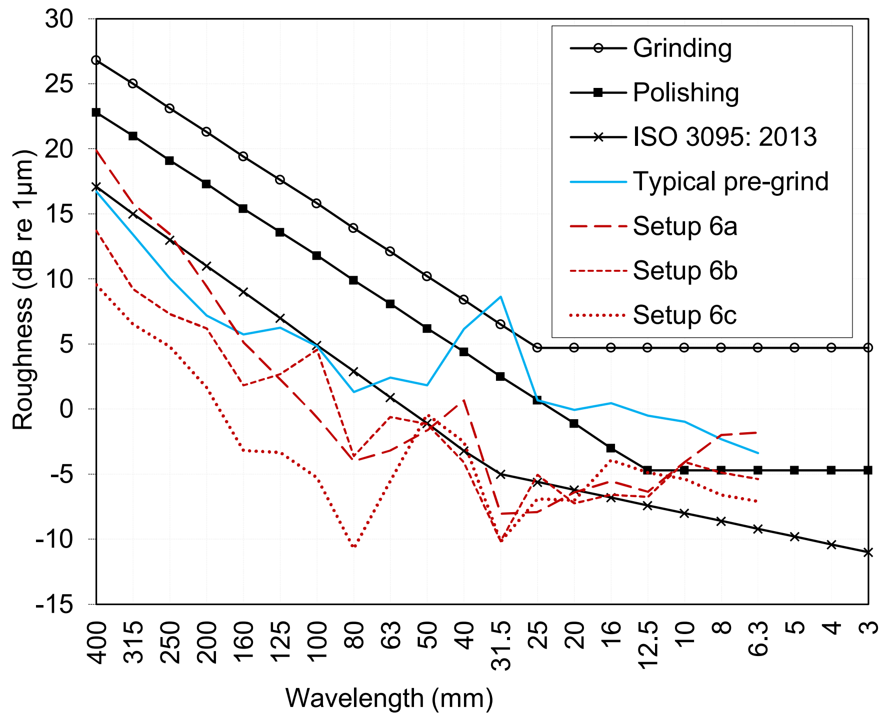
- Setup 1 had been used on other systems, used as first step grinding
- Setup 6 best against polishing specifications

Setup	Stone	Amperage	Grinder Speed	Comment
1	909M	20-22	4 mph	Medium grit for step 1 grinding
2	909F	24	6 mph	Fine grit, high speed polish attempt
3	909F	24	3 mph	Fine grit, low speed polish attempt
4	909XF	22	4 mph	Extra fine grit polish
5	SGAF	22	4 mph	Extra fine, different stone supplier
6	909XF	24	6 mph	Extra fine grit, final preferred setup

Roughness outcomes

Examples of roughness outcomes relative to pre-grind condition and specifications, preferred setup:

- 6a, initial result
- 6b and 6c, outcomes after additional touchup grinding



Noise outcomes – implementation of new specs

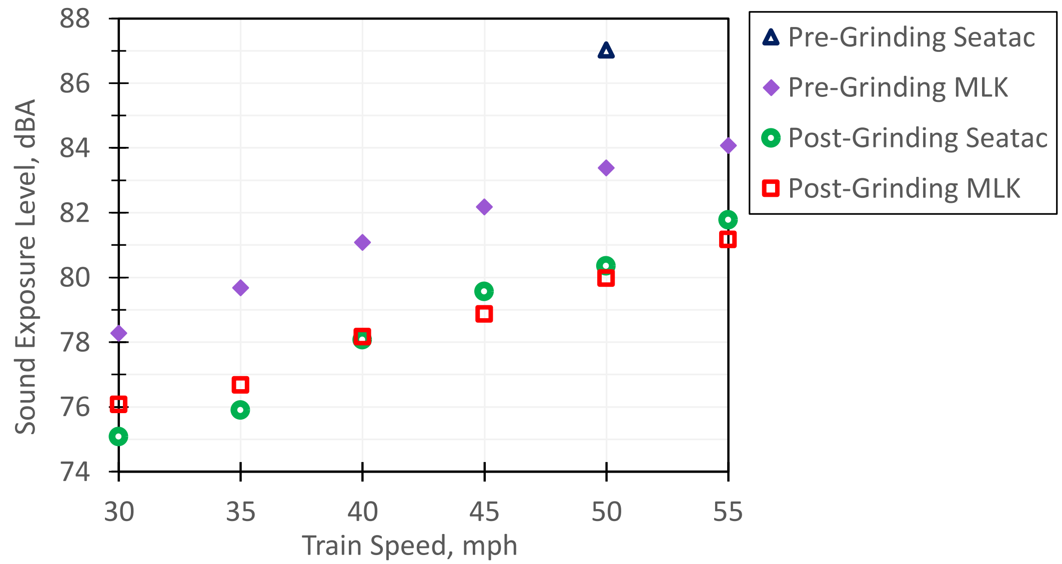
Two sites selected for noise measurements:

- MLK – ballast (multiple speeds possible)

  3-4 dBA noise reduction

- Seatac – direct fix slab (single speed pre-grind)

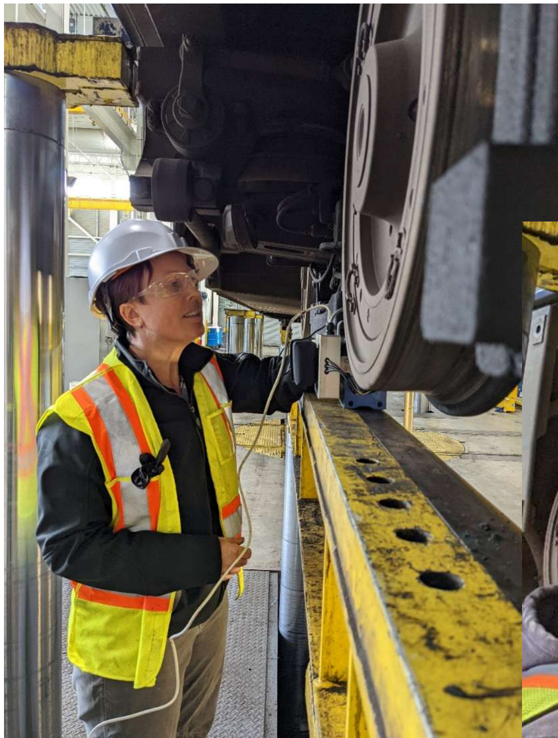
  7 dBA noise reduction

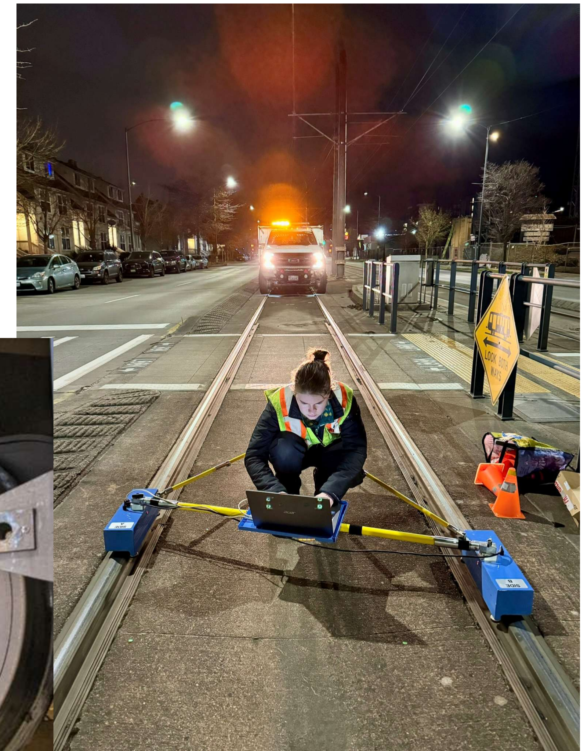


Seatac results have been normalized by subtracting 4 dB to allow comparison with ballast track results (correction as per FTA manual)

All SEL results shown normalized for a single LRV (29m) at 50 feet (15 m)

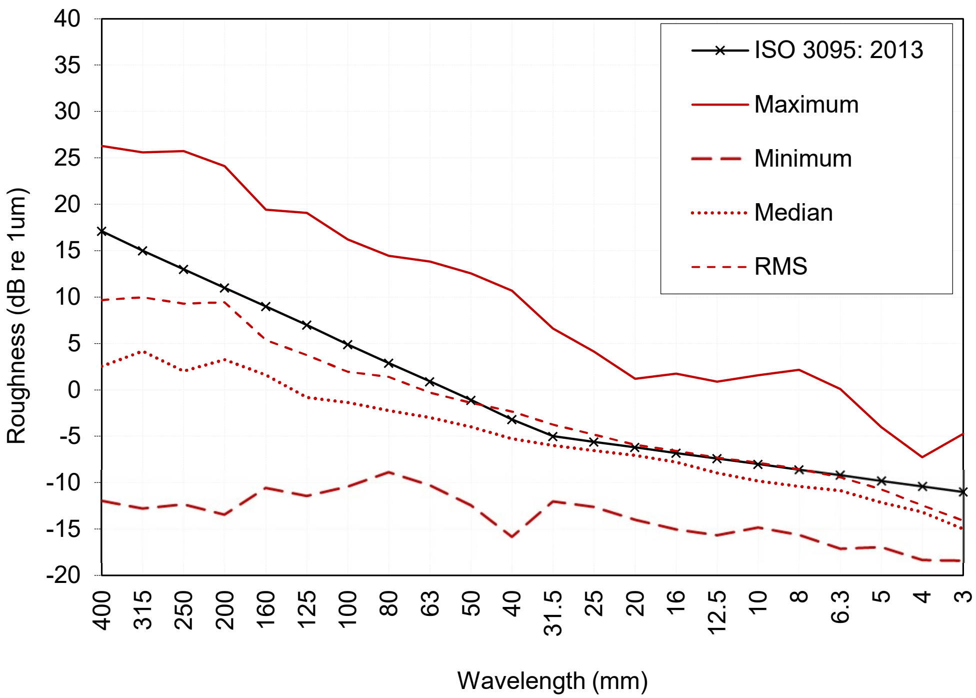
Recent studies (2023 – now)





Detailed investigations of wheel roughness

- Measurements of 204 wheels (124 after quality checks)
- Freshly machined through to 198,000 miles, well beyond typical reprofiling interval
- RMS of all measured wheels similar to ISO 3095:2013
- Wheel roughness in service independent of mileage – freshly machined wheels quickly wear in
- Some outliers, but unrelated to distance travelled
- General wheel acoustic roughness (excluding discrete defects e.g. flat spots) was also independent of the vehicle and truck/bogie type



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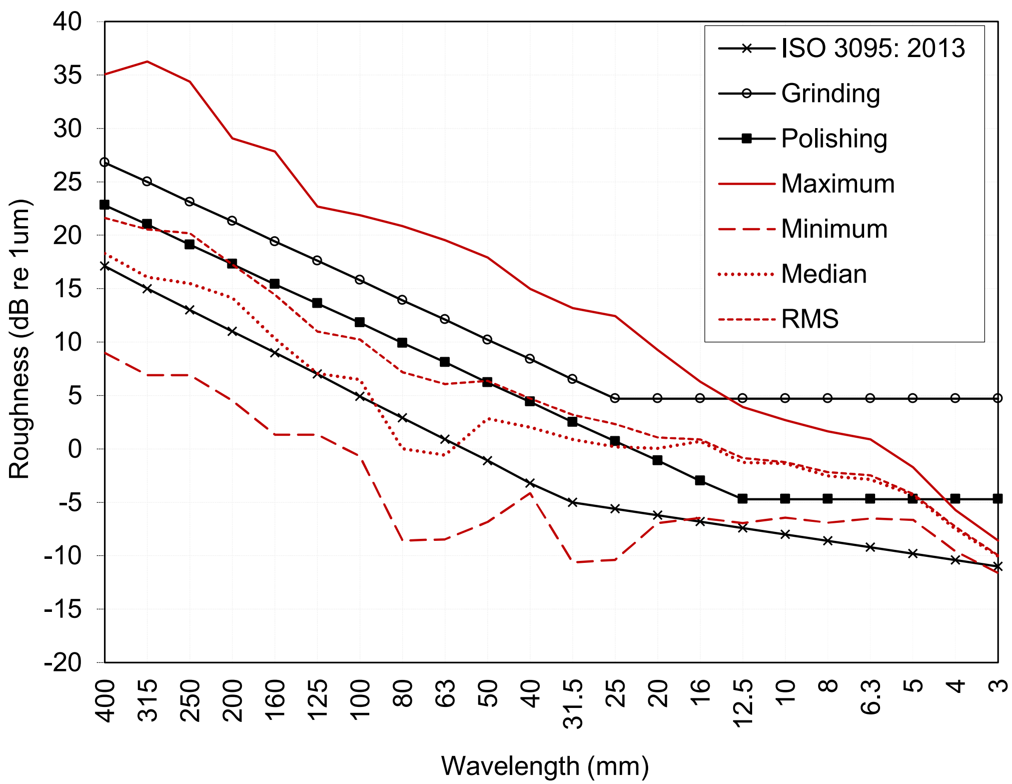
Detailed investigations of rail roughness

Three sites measured:

- Before grinding
- After grinding
- 1 month post grind
- 3 months post grind
- 6 months post grind

RMS roughness of all measured rails was higher than wheels

- close to polishing specification at wavelengths greater than 25mm
- up to 5 dB above polishing specification at shorter wavelengths 5mm up to 25mm



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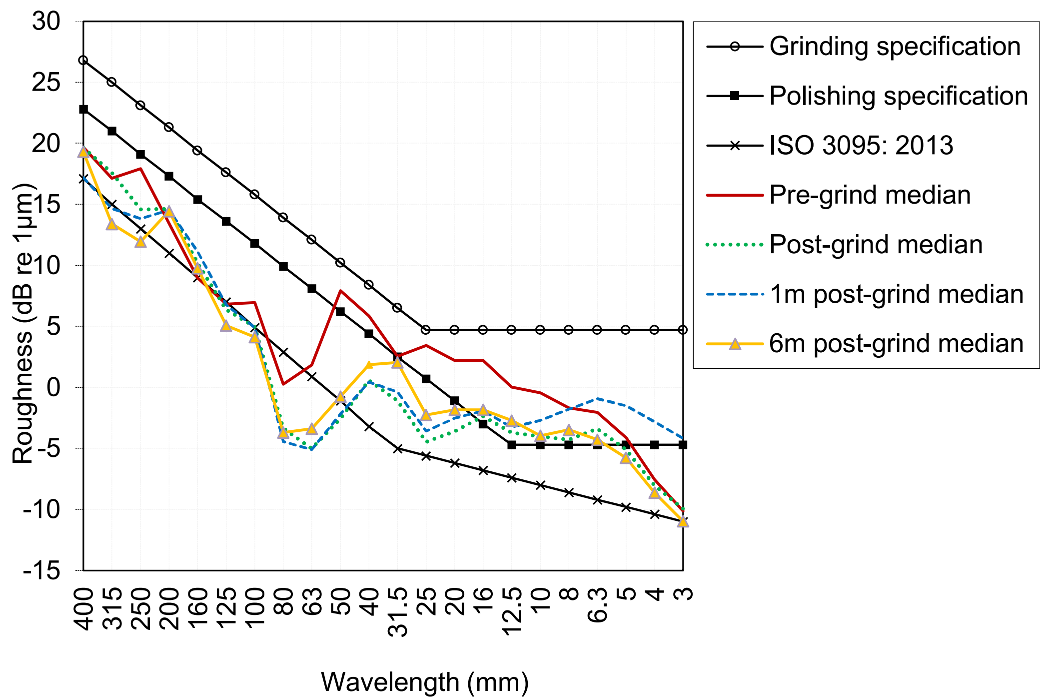
Rail roughness observations

Before grinding typical outcome:

- Roughness peak around 50 mm (residual signature 3 years after grinding at 6mph)
- longer wavelengths < polishing spec
- shorter wavelengths between Seattle grinding and polishing specs

After grinding observations:

- Roughness reduced by grinding and polishing in range of interest for rolling noise
- Dominant peak reverted to 31.5 mm band, (polishing speed not at 6mph target)
- Stable roughness after grinding over 6 months



Around 50% of rails exceed the polishing specification post-grind – maybe due to a reduction in number of polishing passes completed relative to prior years

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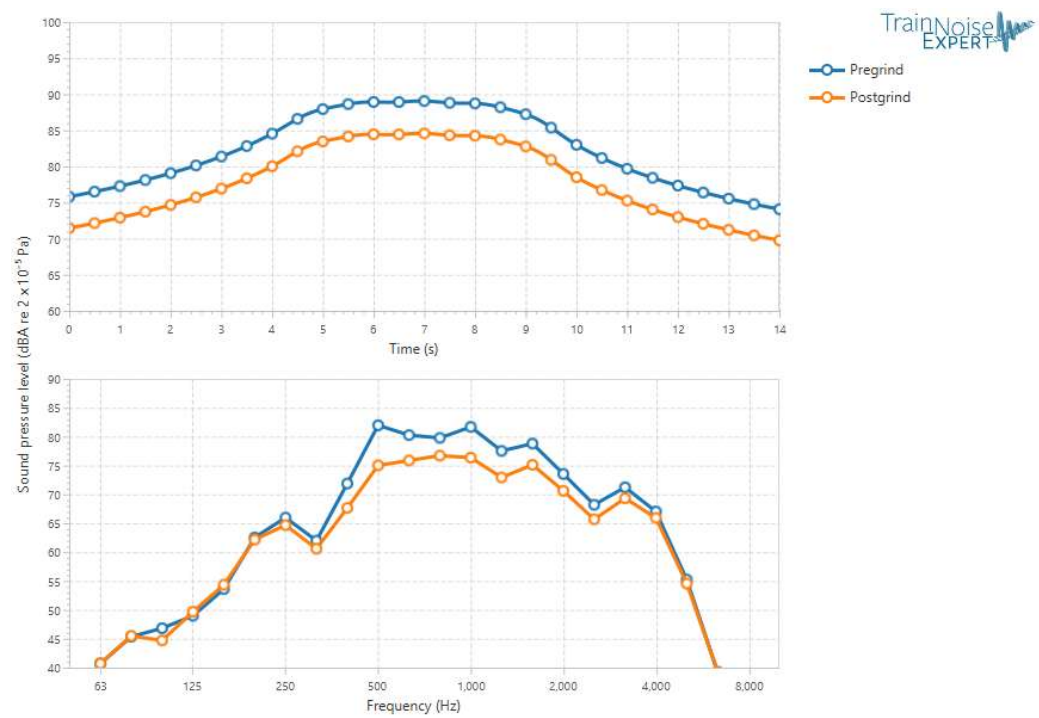
Train Noise Expert modelling

TNE model previously developed and validated:

- median roughness results indicate a 4.5 dBA noise reduction after grinding and polishing

Unusual result - many systems see increased noise after grinding:

- May be related to rail hardness, persistence of rail roughness over time
- Mechanism for increasing roughness later in 3 year grind cycle remains unclear



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Discussion

- Rail grinding in Seattle typically is preventative, to avoid rolling contact fatigue and squat type defects
- Except on new extensions, grinding rarely needed to correct profile degradation - hard rails maintain installed profile with minimal wear
- Relatively stable roughness after grinding suggests an opportunity to minimize noise further
  - By further optimizing existing equipment or with new grinding technologies

Conclusions

- Sound Transit has undertaken a progressive program of improvements to rail grinding strategies and specifications
- This work has reduced noise, by up to 7 dBA in areas with high roughness introduced by coarse grinding to install target rail profiles
- Benefits have largely been maintained over the last five years
- Fleet wheel roughness typically around the ISO 3095 reference spectrum for disc braked wheels, independent of mileage since wheel turning
- Opportunity to extend wheel turning intervals by implementing a data-driven approach supported by automated wheel monitoring, in place of the current defined distance-based maintenance intervals
- Rail roughness still dominates - opportunity to reduce rolling noise further by additional focus on rail grinding quality control and by exploring new acoustic grinding technologies as these become available

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