RAIL REPROFILING: ITS INFLUENCE ON RAILWAY NOISE

Dr Stuart L Grassie  
RailMeasurement Ltd  
tel: +49 5130 375 775  
fax: +49 5130 376 346  
mobile: +44 7803 290 252  
stuart.grassie@railmeasurement.com  
www.railmeasurement.com
acknowledgements

• London Underground
  – John Edwards and James Shepherd, Noise and Vibration Engineers

• SWJTU, Chengdu (post-grind monitoring of corrugation)
  – Prof Xuesong Jin and colleagues

• CAT measurements
  – ARTC, Citirail, Corus/Tata, IRT (Monash), LU, Loram, Metro Medellin, QR, Schweerbau, SL-Ban, SNCF, Sumitomo, Tokyo Metro, TTC and others
scope of presentation

• Why does reprofiling influence railway noise?
  – the contribution of irregularities to air-borne and ground-borne noise

• Different reprofiling techniques:
  – What are they?
  – How much do they influence irregularities?
  – What are their advantages and disadvantages?

• Critical factors for noise reduction by reprofiling
  – robust and practical specification of requirements
  – monitoring of the specification

• conclusions and recommendations
summary (in advance)

Something old, something new
Something different, something true?
Why does reprofiling influence railway noise?

- “model” of wheel/rail noise generation
  - from DJT / TWINS
- See Brian H’s presentation
- “roughness” (wheel and rail) is the input to the model
- therefore input also to wheel/rail noise generation

Fig. 1 A framework for wheel–rail noise generation
reprofiling techniques

• There are several ways to reprofile rails
  – conventional grinding
  – “offset” grinding
  – “shuffle-block” grinding
  – milling
  – planing
  – grinding with approximately transverse axis of rotation
    • not considered here
“conventional” grinding

- modules
  - inclined to vertical
    - transverse reprofiling
    - longitudinal facets
  - rotate about axis normal to rail
    - cut on leading or trailing face of “doughnut”
    - periodic “grinding signature”
- vast majority of grinding trains
“offset” grinding

- grinding stone cuts on side face of doughnut
  - motion relative to rail is mainly longitudinal
    - longitudinal scratches on rail
    - low roughness, low noise
  - ability to reprofile rail transversely is poor
  - blends facets from conventional grinding
  - conventional then offset grind
“shuffle block” grinding

- blocks pushed onto rail
- oscillate to and fro on rail
- blocks adopt transverse profile of rail
  - very limited ability to modify transverse profile
- low metal removal, low productivity
- excellent longitudinal profile, low roughness, low noise
milling and planing

• milling
  – excellent control of transverse profile
  – poor ability to modify transverse profile
  – has a place in reprofil ing, but lacks versatility of grinding

• planing
  – high metal removal rates: change profile
appearance of rails
conventional and offset grinding

• conventional grinding leaves periodic stone “signature”

• offset has *insignificant* signature: low longitudinal roughness
appearance of rails milling and planing

• milling leaves small “cusps” from cutters
  – can remove these with a block grinder if noise is critical

• planing can leave severe longitudinal grooves
  – downside of high metal removal rate
How much do irregularities influence air-borne noise?

- >10dB increase in noise with corrugation ("short" wavelength)
- **removal** of irregularities can reduce noise by >10dB
How much do irregularities influence ground-borne noise?

- in-property noise reduction correlates well with reduction in “roughness” in 100-1000mm wavelength range
  - 20-200Hz for 20m/s (50mph)
  - 25-250Hz considered the range for “audible ground-borne noise”
- expect in-vehicle noise to correlate with 10-100mm
  - reduction in 30-100mm roughness is twice the reduction in ground-borne noise

Data courtesy of James Shepherd, N&V Engineer, London Underground.
equipment to measure corrugation and acoustic roughness
EN 13231-3:2006

Table 1 — Window lengths

<table>
<thead>
<tr>
<th>Wavelength range (mm)</th>
<th>0 - 30</th>
<th>30 - 100</th>
<th>100 - 300</th>
<th>300 - 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window length (m)</td>
<td>0.15</td>
<td>0.5</td>
<td>1.5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2 — Moving average of RMS amplitude limits

<table>
<thead>
<tr>
<th>Wavelength range (mm)</th>
<th>10 - 30</th>
<th>30 - 100</th>
<th>100 - 300</th>
<th>300 - 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit of moving average of RMS amplitude (mm)</td>
<td>0.004</td>
<td>0.004</td>
<td>0.012</td>
<td>0.040</td>
</tr>
</tbody>
</table>

Table 3 — Moving average of peak-to-peak amplitude limits

<table>
<thead>
<tr>
<th>Wavelength range (mm)</th>
<th>10 - 30</th>
<th>30 - 100</th>
<th>100 - 300</th>
<th>300 - 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit of moving average of peak-to-peak amplitude (mm)</td>
<td>0.010</td>
<td>0.010</td>
<td>0.030</td>
<td>0.100</td>
</tr>
</tbody>
</table>

Table 4 — Acceptance criteria for longitudinal profile expressed in terms of allowable percentages of track exceeding moving average RMS or peak-to-peak amplitude limits

<table>
<thead>
<tr>
<th>Wavelength range (mm)</th>
<th>10 - 30</th>
<th>30 - 100</th>
<th>100 - 300</th>
<th>300 - 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>5 %</td>
<td>5 %</td>
<td>5 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Class 2</td>
<td>No requirement</td>
<td>10 %</td>
<td>10 %</td>
<td>No requirement</td>
</tr>
</tbody>
</table>

• This is an excellent and practical basis for reprofiling specifications to reduce wheel / rail rolling noise

0.010mm = 0.4thou

most significant wavelength ranges for noise
character of typical irregularities / “acoustic roughness” on a rail

- all measurements taken with CAT
- from users worldwide
- all “types” of railway system
  - heavy haul
  - mixed passenger and freight
  - metro
  - light rail / tram
- data from pre- and post-reprofiling from all major suppliers (Harsco, Loram, Speno)
presentation of data

- Left hand graph shows typical roughness superposed on EN ISO3095 roughness for “smooth” rail
  - “natural” feature of surfaces is that roughness decreases with wavelength
- RH graph shows difference from ISO3095 (same data)
metro and light rail / tram

• metro and light rail systems have very “peaky” corrugation
  – tightly controlled speeds,
    ∴ wavelength = speed/frequency is constant

• tram / LR systems typically have high roughness at short wavelength
  – sand
heavy haul and mixed traffic

- **heavy haul railways**
  - roughness is generally very low
  - peaks from sleeper spacing and grinding

- **mixed traffic railways**
  - corrugation peaks are broad (variation in speed)
  - *generally* low short wavelength roughness
reprofiling to reduce irregularities

- almost identical
  - EN ISO3095 level for “smooth” rail
  - EN13231-3:2006 level for reprofiling

ENISO3095:2005

EN13231-3:2006

RAIL TRANSIT SEMINAR • MAY 3, 2011
WRI 2011
post-reprofiling roughness

Shown relative to quasi-ISO3095 spectrum

- from many railway systems worldwide
  - huge range of roughness: some v. good, some v.poor
  - characteristic grinding signature at 20-25mm
  - good milling not significantly different from good grinding
  - principal problem is poor specification and control of reprofiling quality
difference between pre- and post-grind

- **20dB increase** in *worst* case
  - short wavelength significant for noise
- **20-30dB reduction** in *best* case
  - more typical reductions are 5-10dB
typical problems
what is possible and what should be avoided?

• minimise
  – “grinding signature”
    (typically 20-30mm wavelength)
    – short wave roughness

“good” grinding:
- residual corrugation < 5µm
- spectrum below ISO3095

grinding poorer:
- residual corrugation
- high roughness
- spectrum well above ISO3095
development of corrugation
(on metro)

- 30-100mm corrugation (measured with CAT)
  - well developed after only 2 months
removal of corrugation (same site)
Loram LR series grinder

- reduction in 30-100mm corrugation: 12 passes
  - > 0.050mm RMS initially
  - < 0.003mm (0.12 thou) RMS after 12 passes
- measurements (at 1mm interval) during grinding
Conclusions (1 of 3)

• There are many ways of reprofiling rails.
• All of these methods reduce noise insofar as all reduce corrugation.
• The extent to which the reprofiling methods reduce noise depends on the extent to which they reduce roughness / corrugation in the critical wavelength range.
  – about 3-250mm (1”-10”) for air-borne noise
  – about 100-1000mm (4”-40”) for ground-borne noise
    (for metro / transit systems)
Conclusions (2 of 3)

• “conventional” grinding, using modules rotating about an axis normal to the rail, is the most common reprofiling technique
  – can do a very good job of removing irregularities 30-300mm
  – less good at <30mm (grinding “signature”)

• milling leaves a similar finish to good conventional grinding

• “offset” and “shuffle-block” grinding are the best way of reducing short wave roughness (<30mm)
  – “acoustic grinding”
Conclusions (3 of 3)

• Greater than 10dB reduction in air-borne and in ground-borne noise is possible from grinding.

• It is also possible for grinding to increase roughness (and therefore also noise) levels.

• Critical requirements are:
  – a specification that is robust, relevant and achievable
  – monitoring of that specification with equipment that is “fit for purpose”

• Such equipment exists and is used routinely on many railway systems and by many contractors, consultants and suppliers worldwide.