RAIL REPROFILING:
ITS INFLUENCE ON RAILWAY NOISE

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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?

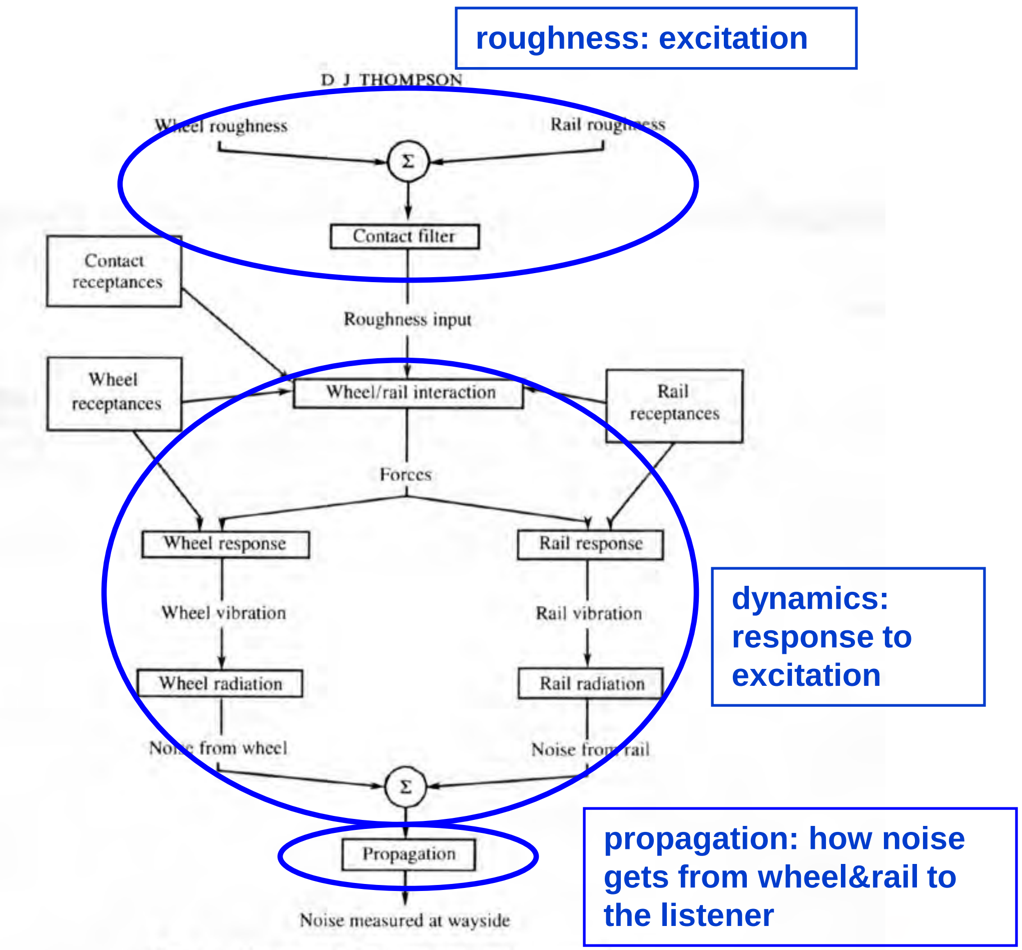


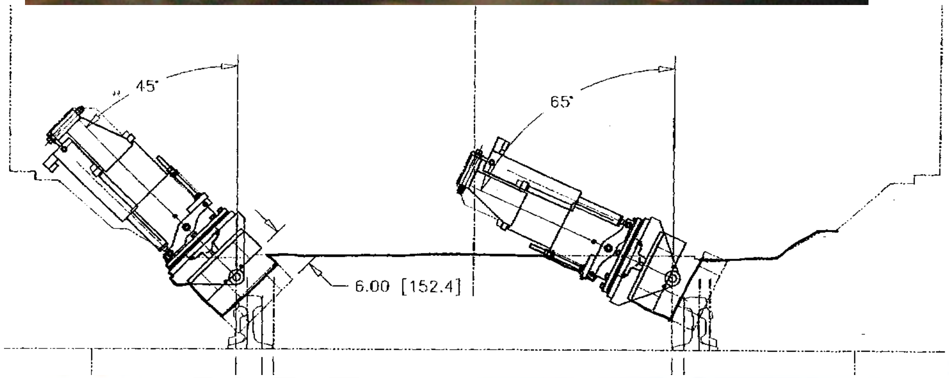
Fig. 1 A framework for wheel–rail noise generation

- "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

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

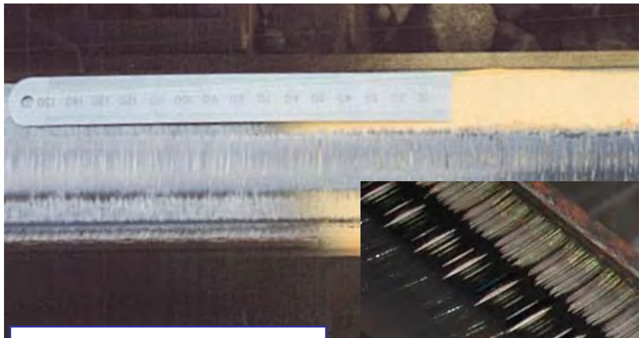
- blocks pushed onto rail
- oscillate to and fro on rail
- blocks adopt transverse profile of rail
  - very limited ability to modify transverse profile
- low metal removal, low productivity
- excellent longitudinal profile, low roughness, low noise

milling and planing

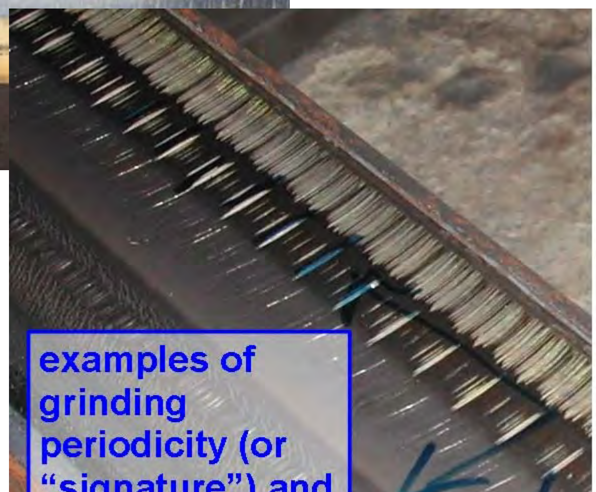
- milling
  - excellent control of transverse profile
  - poor ability to modify transverse profile
  - has a place in reprofiling, but lacks versatility of grinding
- planing
  - high metal removal rates: change profile

appearance of rails
conventional and offset grinding

- conventional grinding leaves periodic stone “signature”
- offset has *insignificant* signature: low longitudinal roughness



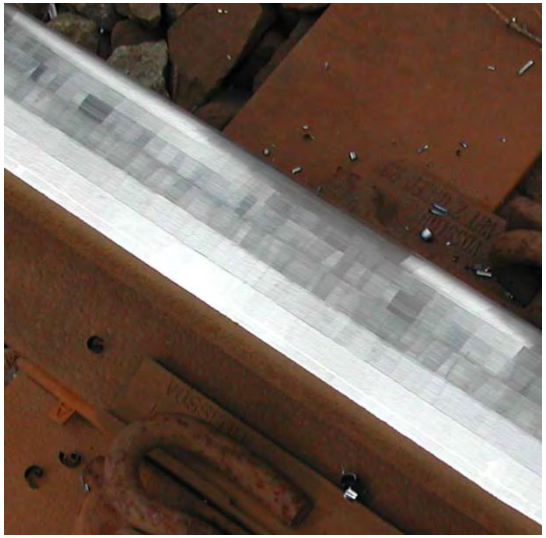
good conventional grinding

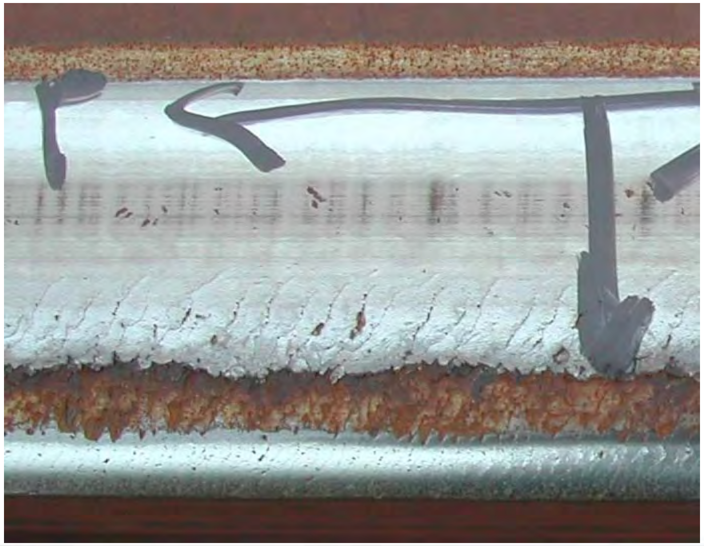


examples of grinding periodicity (or “signature”) and rough finish

offset grinding

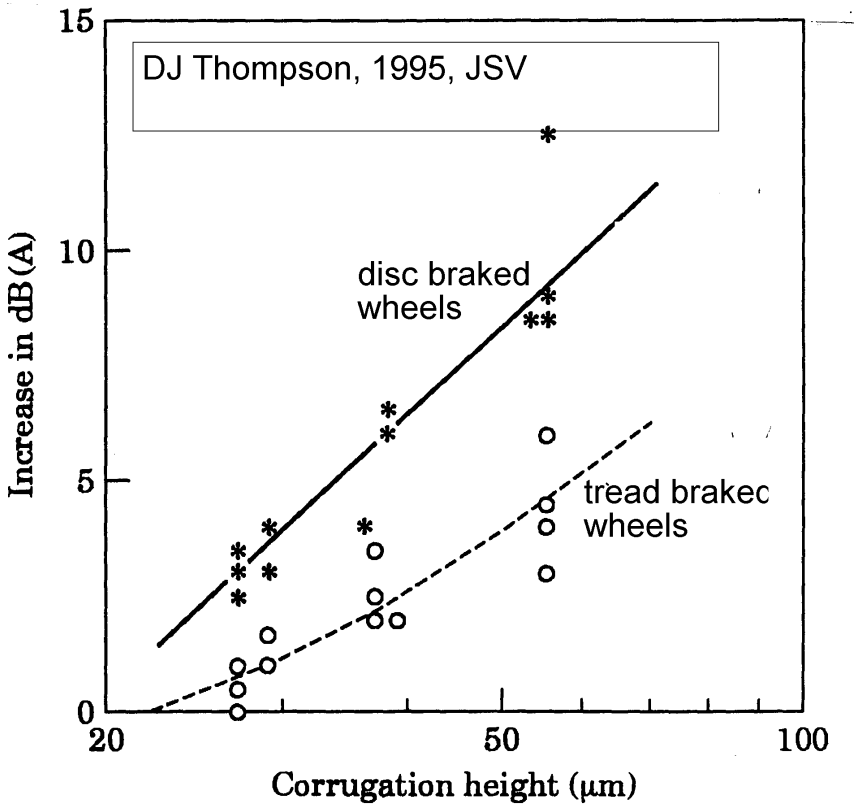
appearance of rails
milling and planing





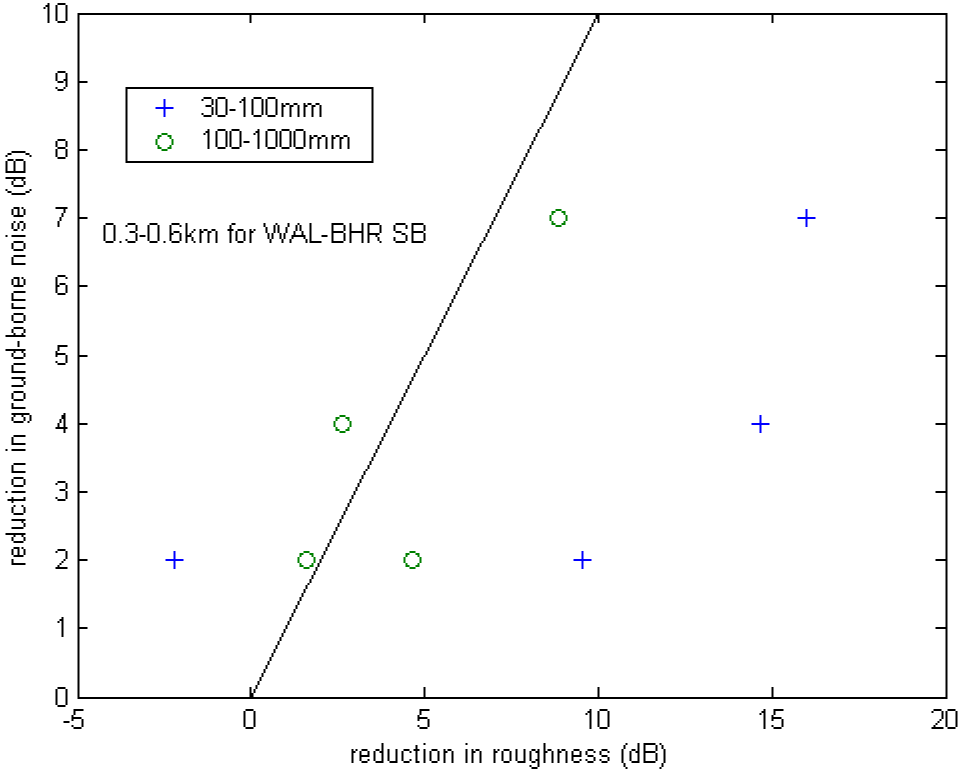
- milling leaves small “cusps” from cutters
  - can remove these with a block grinder if noise is critical
- planing <u>can</u> leave severe longitudinal grooves
  - downside of high metal removal rate

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?



data courtesy of James Shepherd, N&V Engineer, London Underground

- 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

equipment to measure corrugation and acoustic roughness

EN 13231-3:2006

most significant wavelength ranges for noise

Table 1 — Window lengths

Wavelength range (mm)	10 - 30	30 - 100	100 - 300	300 - 1 000
Window length (m)	0,15	0,5	1,5	5

Table 2 — Moving average of RMS amplitude limits

Wavelength range (mm)	10 - 30	30 - 100	100 - 300	300 - 1 000
Limit of moving average of RMS amplitude (mm)	0,004	0,004	0,012	0,040

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

Wavelength range (mm)	10 - 30	30 - 100	100 - 300	300 - 1 000
Limit of moving average of peak-to-peak amplitude (mm)	0,010	0,010	0,030	0,100

0.010mm = 0.4thou

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

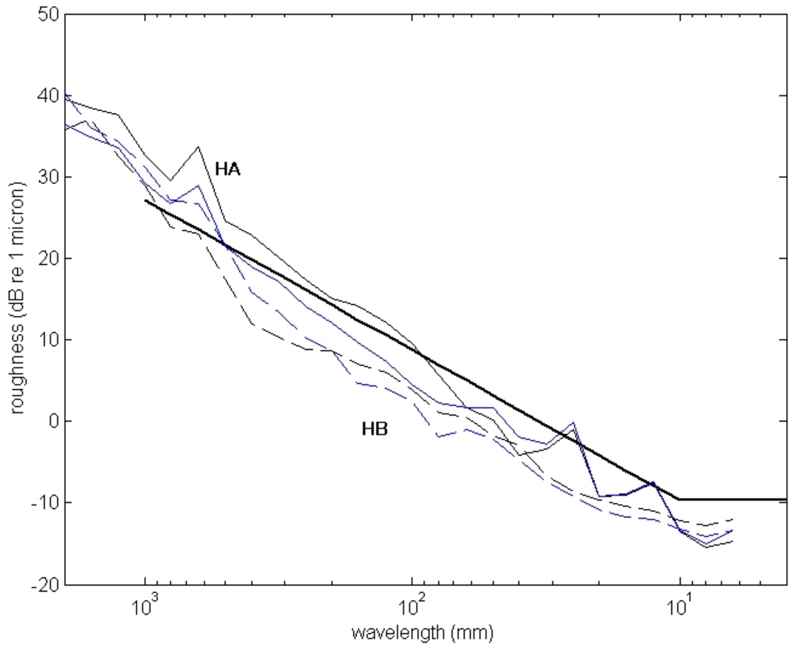
Wavelength range (mm)	10 - 30	30 - 100	100 - 300	300 - 1 000
Class 1	5 %	5 %	5 %	10 %
Class 2	No requirement	10 %	10 %	No requirement

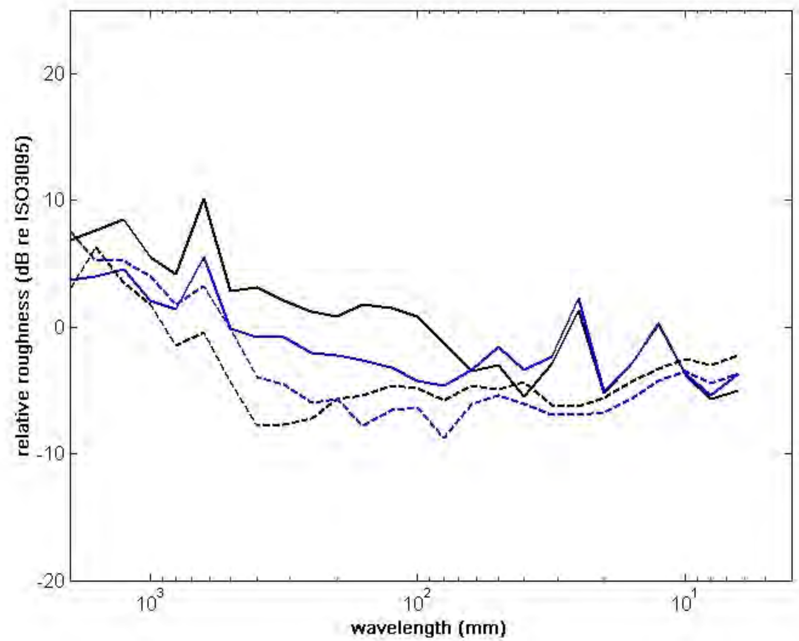
- This is an excellent and practical basis for reprofiling specifications to reduce wheel / rail rolling noise

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)

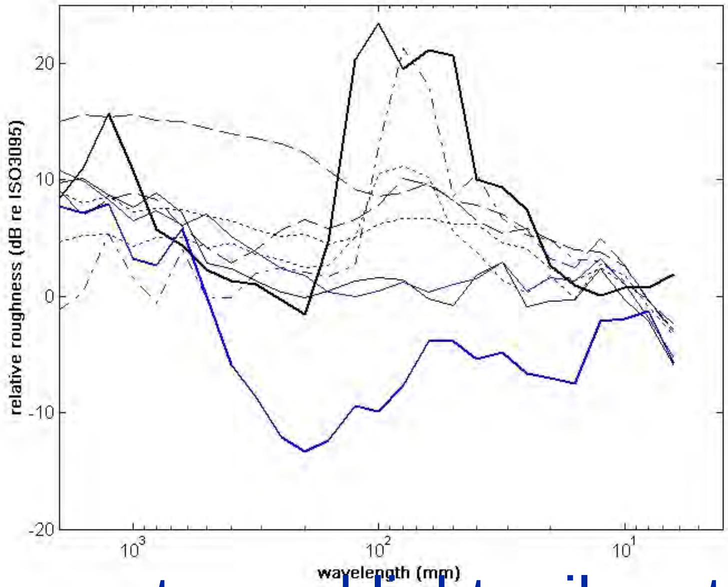
presentation of data

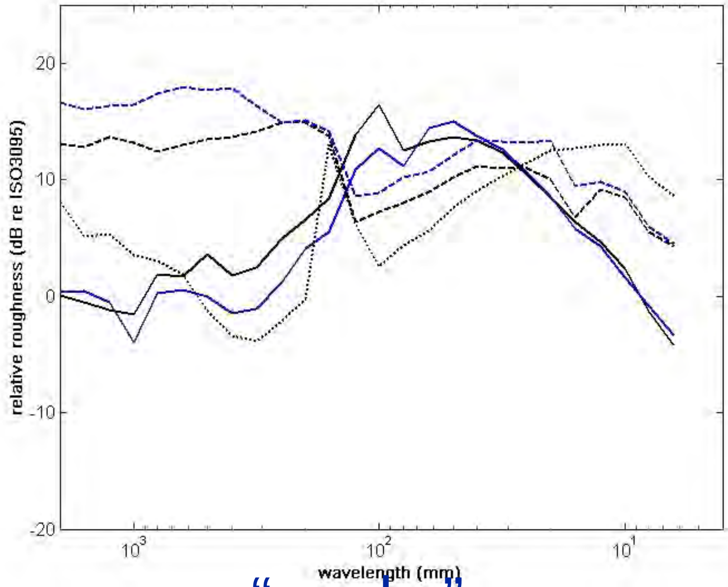




- left hand graph shows typical roughness superposed on EN ISO3095 roughness for “smooth” rail
  - “natural” feature of surfaces is that roughness decreases with wavelength
- RH graph shows <u>difference</u> from ISO3095 (same data)

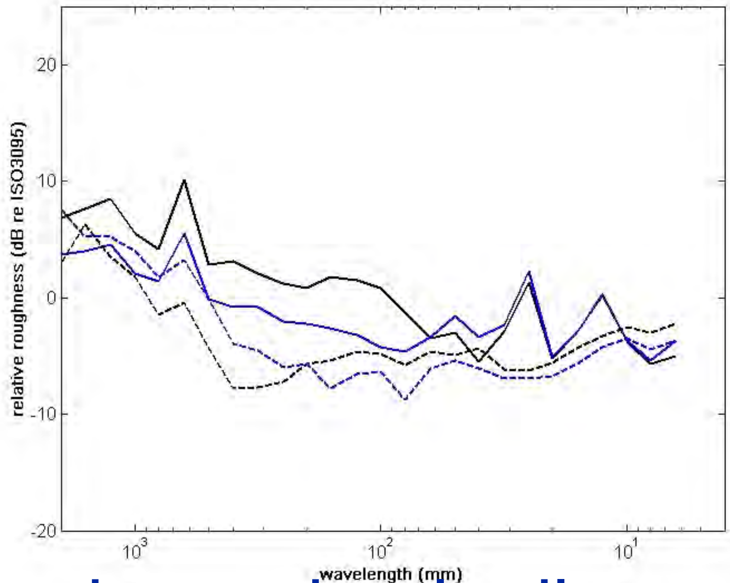
metro and light rail / tram

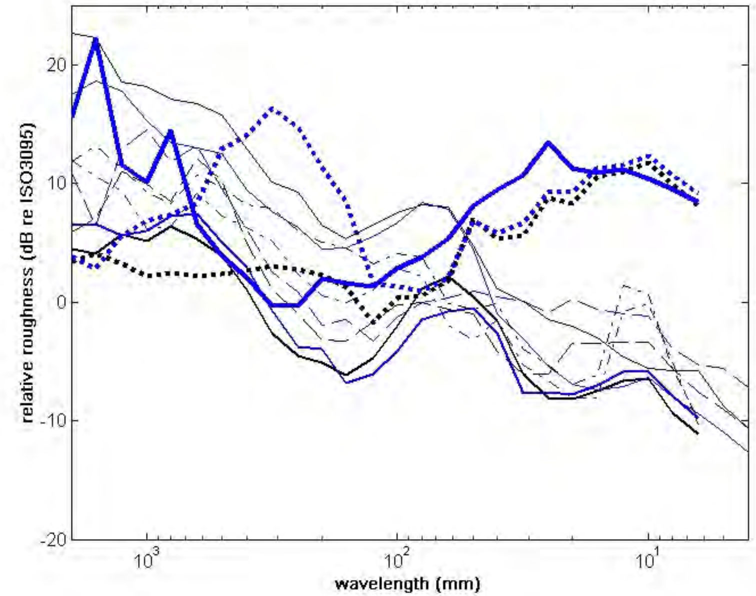




- metro and light rail systems have very “peaky” corrugation
  - tightly controlled speeds,
    - ∴ wavelength = speed/frequency is constant
- tram / LR systems typically have high roughness at short wavelength
  - sand

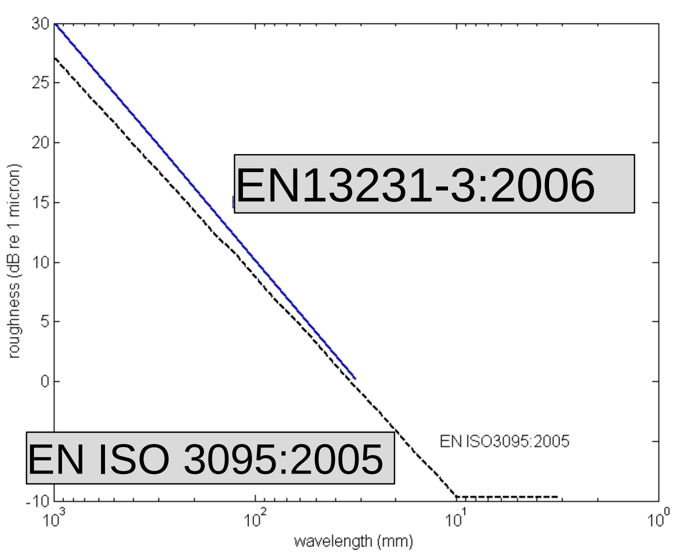
heavy haul and mixed traffic

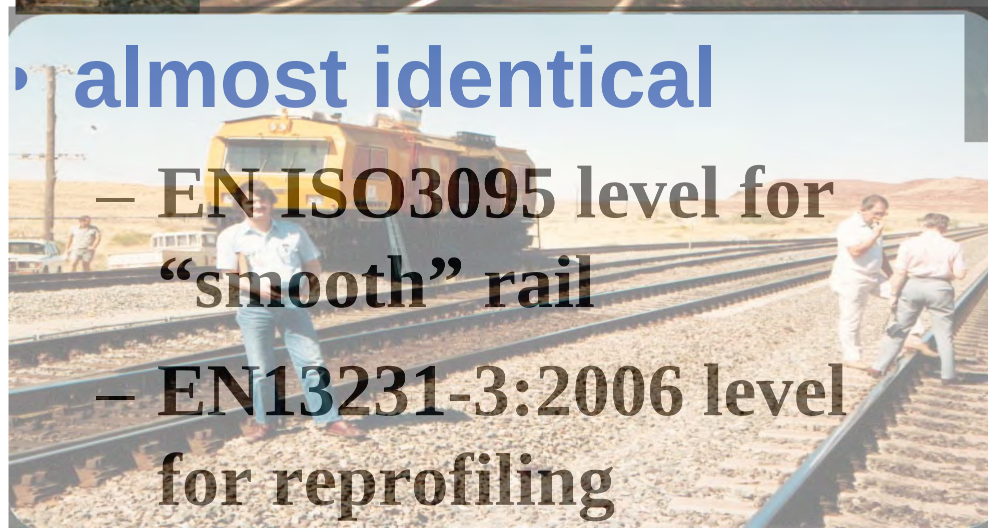




- heavy haul railways
  - roughness is generally v. low
  - peaks from sleeper spacing and grinding
- mixed traffic railways
  - corrugation peaks are broad (variation in speed)
  - *generally* low short wavelength roughness

reprofiling to reduce irregularities

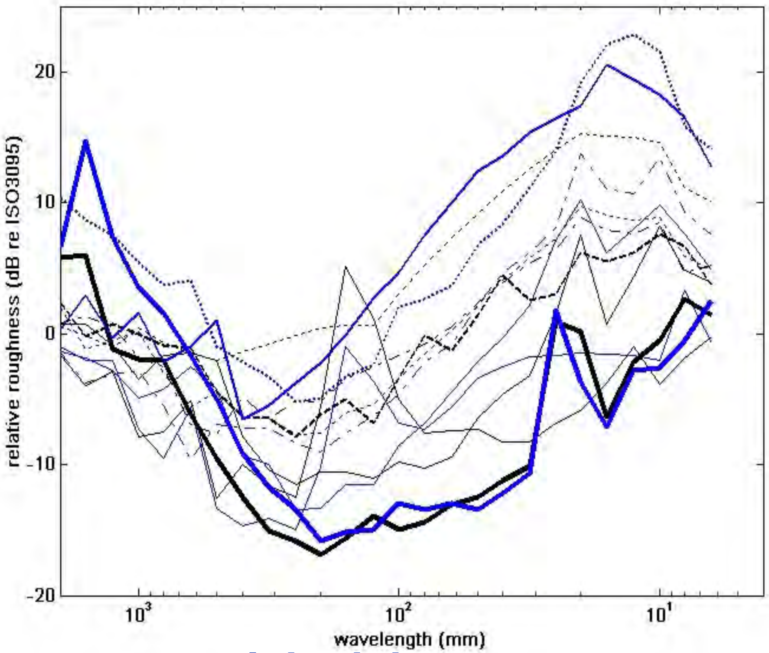




- almost identical
  - EN ISO3095 level for "smooth" rail
  - EN13231-3:2006 level for reprofiling

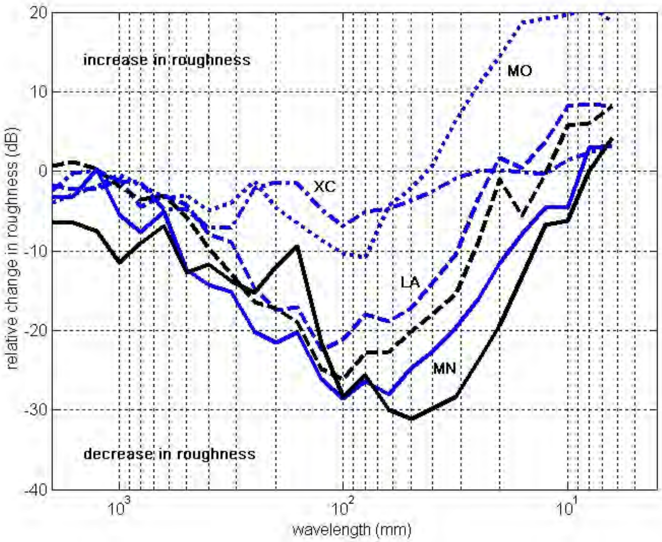
post-reprofiling roughness

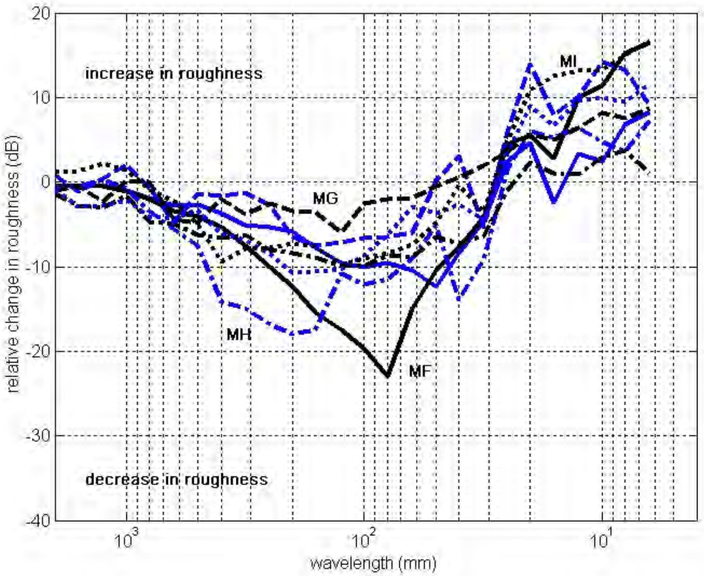
Shown relative to quasi-ISO3095 spectrum



- 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

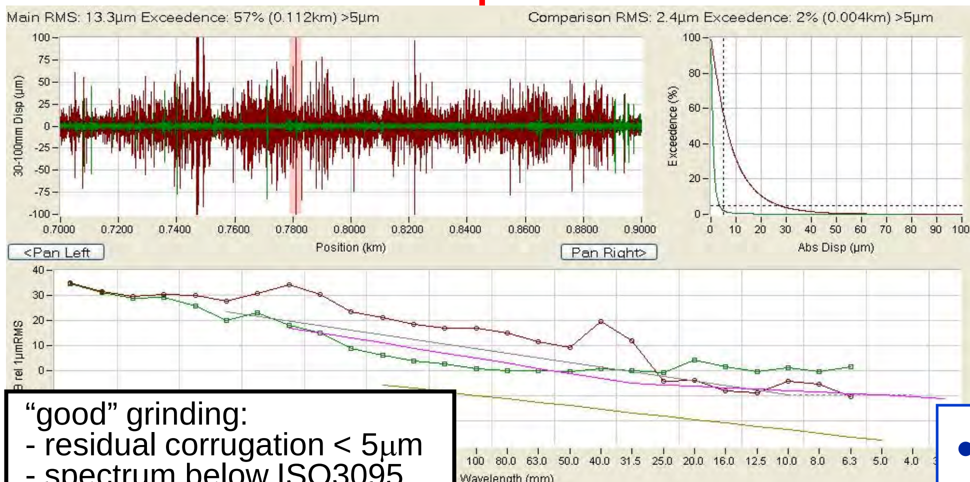




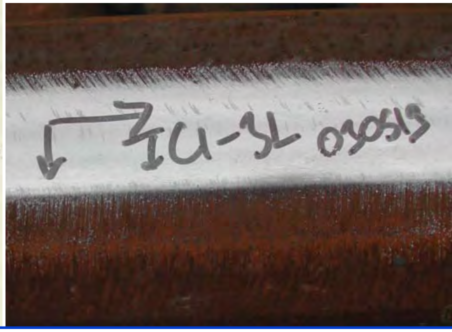
- 20dB <u>increase</u> in *worst* case
  - short wavelength ∴ significant for noise
- 20-30dB <u>reduction</u> in *best* case
  - more typical reductions are 5-10dB

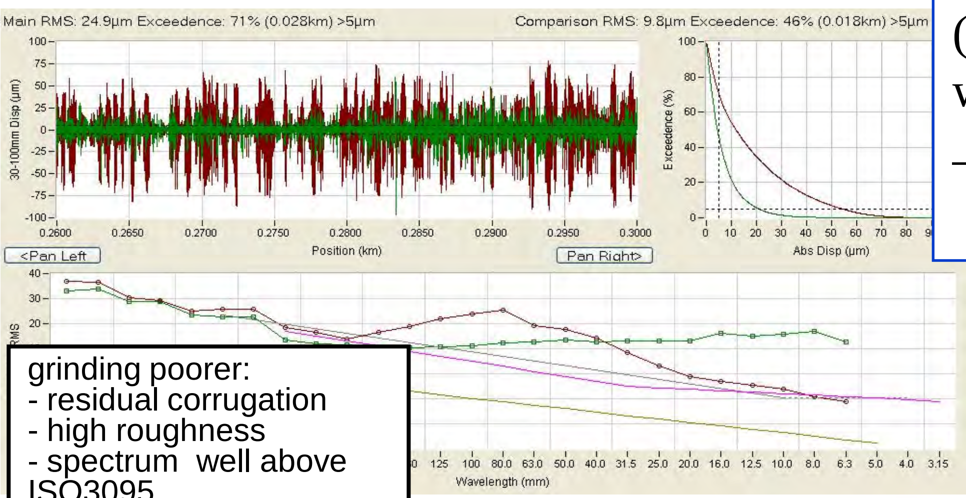
typical problems

what is possible and what should be avoided?



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





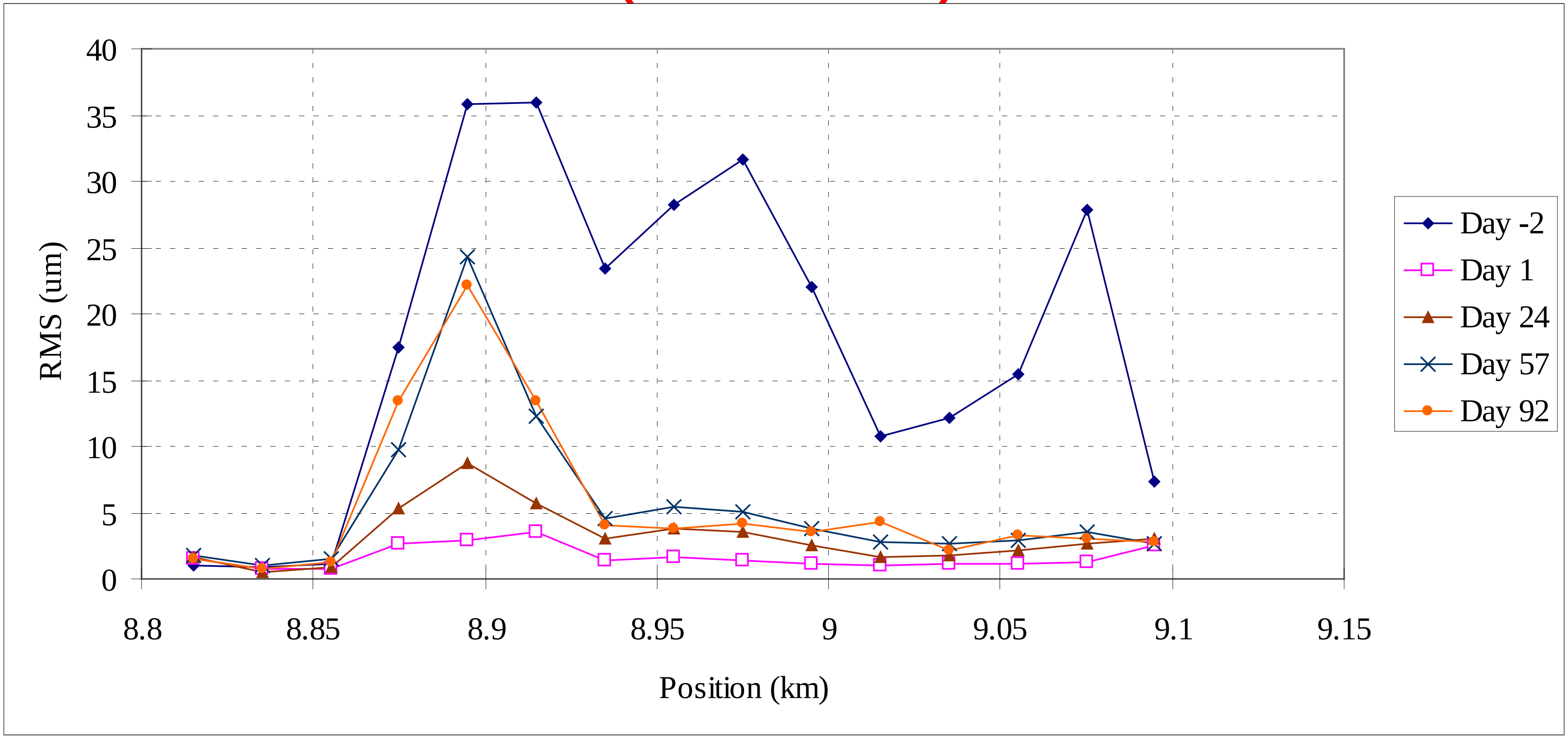
grinding poorer:
- residual corrugation
- high roughness
- spectrum well above ISO3095

•minimise

–“grinding signature” (typically 20-30mm wavelength)

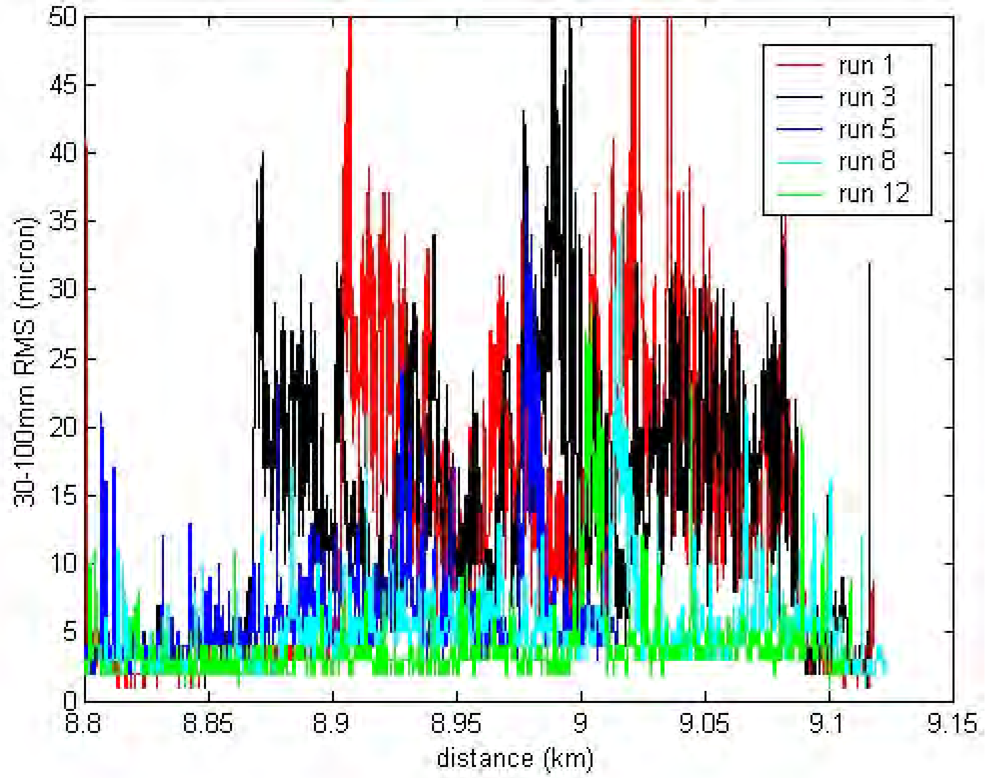
–short wave roughness

development of corrugation
(on metro)



- 30-100mm corrugation (measured with CAT)
  - well developed after only <u>2 months</u>

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 <u>in the critical wavelength range.</u>
  - 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 <u>increase</u> 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.