24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

DISCUSS ON THE ACCEPTANCE CRITERIA FOR ACOUSTIC RAIL GRINDING

Hougui ZHANG, Bin ZHANG, Lijuan ZHANG

Beijing Municipal Institute of Labour Protection, Beijing 100054, China
Email: hugo.zhg@icloud.com

Hougui ZHANG, Markus HECHT

Technical University of Berlin, Faculty V of Mechanical Engineering and Transport Systems, Germany

Abstract: Railway noise generation depends to a large extent by the rail and wheel roughness as well as corrugation. A special procedure called acoustic grinding is therefore undertaken to achieve a smooth rail for reducing noise. However, even the acceptance of grinding work satisfy the requirement of standard EN 13231-3:2012, it can be "unacceptable noise " in practice. This may be because of track specific values that were defined at too low a level. It is reasonable to update the grinding work standard. Based on a mathematical calculation, the recommendation acceptance criteria for acoustic rail grinding was discussed in this presented paper. After that, a case study conducted for Beijing metro was also provided as an example .
Keywords: railway acoustic, rail grinding standard

1. Introduction

A number of railway administrations are currently looking at acoustic rail grinding as a solution of noise reduction in the European policy. In order to limit irregularities that can exist on rails after re-profiling, EN 13231-3 was taken out in 2006 and updated in 2012 for the acceptance of rail grinding, milling and planning work in track[1,2]. The current version of EN 13231-3 states the limited value in terms of peak-to-peak amplitudes by four wavelength bands, as a negotiation of grinding work in practice that is always required how many depth metal should be removed.

However, based on the comprehensive understanding of the rolling noise excitation mechanism, the variation of the height of the rail running surface associated with rolling noise. Whereas the EN 13231-3:2012 reference specifies how much irregularities can be achieved after rail grinding, it does not ensure that wheel/rail noise is low[3]. Although railway administrations agree that rail grinding provides a nominal 3 dB noise reduction, but the assumed benefit is usually not reached in reality. This may be because of track specific values that were defined at too low a level, that the roughness growth is too different from the time linear increase assumed or the grinding is not accurate enough. [4]

In another side, although ISO3095:2013[5] is intended specifically for qualifying a test track for pass-by noise measurement, it also provides a standard to describe the level of roughness for what is essentially a quiet or quieter railway in practice. Since the application and object are entirely independently on EN 13231-3:2012 and ISO3095:2013, gap was made when the rail grinding is conducted.

In order to provide a specification for the acceptance work of acoustic rail grinding, a recommendation criteria was discussed in this presented paper. And a case study conducted for Beijing metro was also provided as an example .

2. What is the gap between grinding work and noise?

A measurement was taken for an example to introduce how much the gap between " accepted re-profiling" and " low noise" after rail grinding.

2.1 Measurement background

The measurement is undertaken in Beijing metro line4 on only one day after a re-profiling work for removing serious rail corrugation. Roughness was measured using a corrugation analysis trolley (CAT) (Figure1:). CAT is a hand operated device for measurement of longitudinal rail irregularities in the wavelength range from approximately 10mm to 3000mm. Rail irregularities are determined by integrating the signal from a vertical accelerometer mounted on a hard steel ball which rolls on the rail. Another wheel with rubber coating is used to determine the longitudinal position of the trolley and to trigger the samples. The sampling distance was 1mm. The data acquisition hardware was connected to a PC via a USB interface[6].

Figure 1: rail roughness measurement

2.2 Data processing based on DIN 13231-3:2012

Firstly, the data processing was carried out based on the procedure of DIN13231-3:2012. The re-quirement of standard and the measured percentages of exceeding was listed in Table 1,while the visually results of flitted peak-to peak value were presented in Figure 2 to Figure 5 .

Table 1: Data processing based on DIN 13231-3:2012

Wavelength range (mm)	10 to 30	30 to 100	100 to 300	300 to 1 000
Limit of peak-to-peak values (mm)	± 0,010	± 0,010	± 0,015	± 0,075
Allowable percentages of exceeding	5 %	5 %	5 %	5 %
Measured percentages of exceeding	0%	0%	0%	22%
Grinding quality	Accepted	Accepted	Accepted	No

It is clearly from Table1 that although the residual roughness in the range from 300mm to1000mm was not satisfying the standard requirement , the grinding work in this case could also be accepted as a "very good" quality.

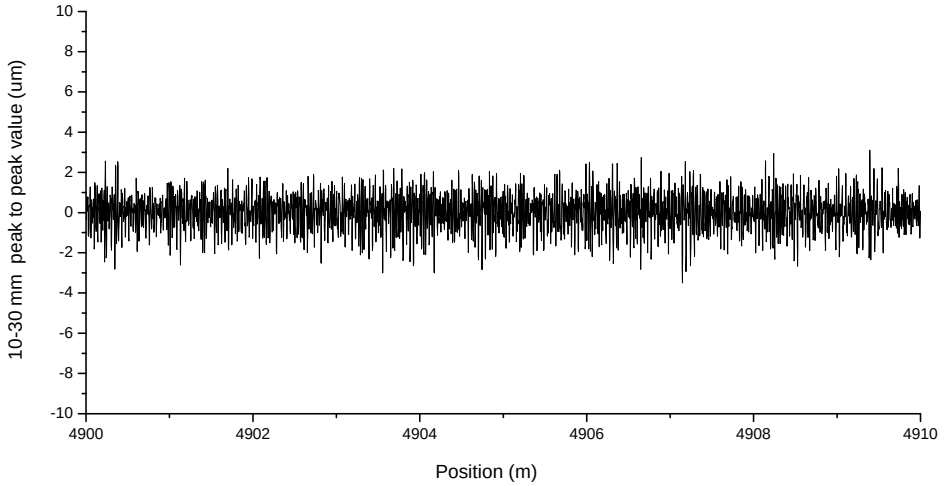

Figure 2: 10~30mm peak to peak value

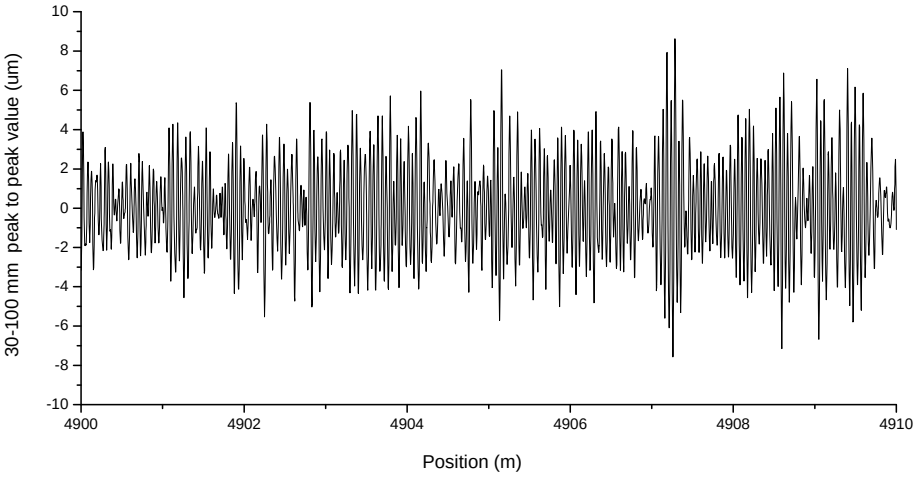

Figure 3: 30~100mm peak to peak value

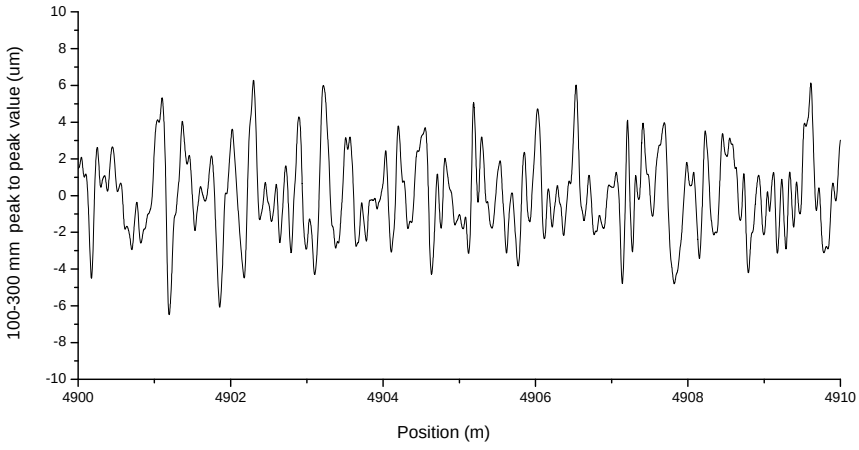

Figure 4: 100~300mm peak to peak value

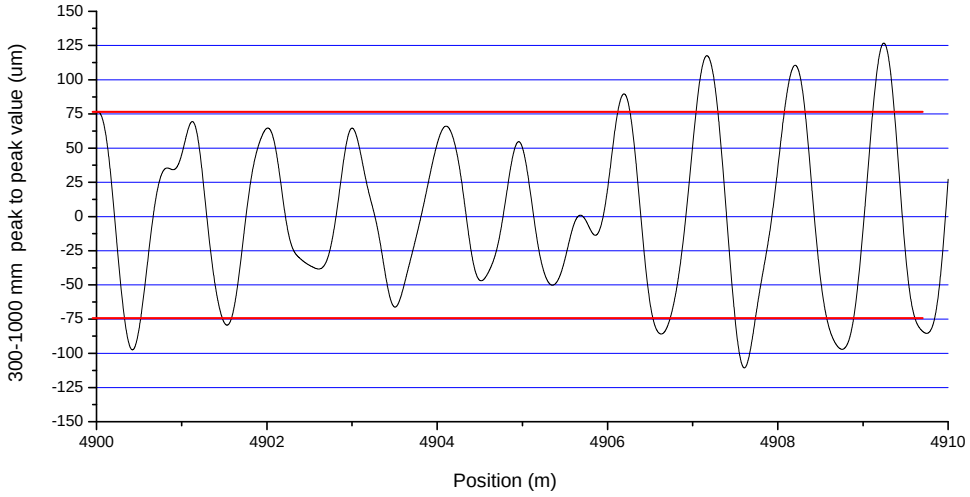

Figure 5: 300~1000mm peak to peak value

2.3 Data processing based on ISO 3095:2012

As a comparison , the measurement data was also present in the form of ISO 3095:2013.The roughness spectrum was also calculated using the mat-lab procedure provided by the standard EN 15610:2009[7].

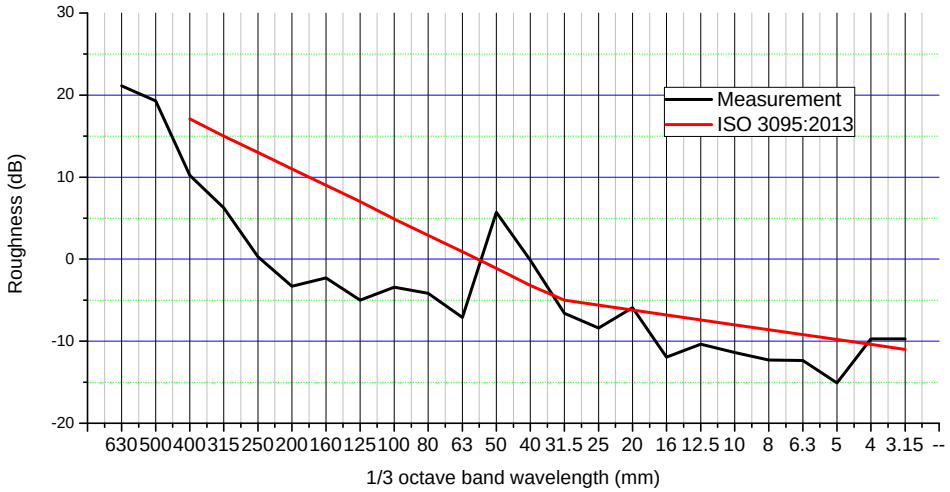

Figure 6: The measurement spectrum Vs. ISO3095:2013

Figure6 shows that there is an obvious peak at the 50mm wavelength band, and associated with the noise around 300Hz when the train speed is at 60 km/h. As it was 6.8 dB higher than the limited value , this section is still under unacceptable noise after grinding.

3. Represent the ISO3095 in the form of EN 13231

In order to control the grinding quality required in EN13231-3 and also keep the noise satisfying the standard ISO 3095. This paper provide a mathematical method to fill the gap between ISO 3095 and EN 13231.

3.1 Basic definition

Generally, the periodic rail profile can be represented as the sum of simple cosine waves and expressed in the form of Fourier series as below.

$$F(x) = a_0 + \sum_{i=1}^{n} A_i \cos(\omega_i x + \theta_i) \tag{1}$$

Where $\omega_i = \frac{2\pi}{\lambda_i}$, A_i is roughness amplitude, λ_i is roughness wavelength

Normally, since the coordinate is always shifted to Zero after filtered, that made $a_0 = 0$. The rail profile can represented as

$$F(x) = \sum_{i=1}^{n} A_i \cos(\omega_i x + \theta_i) \tag{2}$$

Based on the Continuous Fourier transform and Parseval's theorem, the total Root-mean-square can be calculated though sum of simple cosine waves.

$$G^2{}_{total} = \frac{1}{n-1} \sum_{i=1}^{n} G^2_{rms}(\omega_i) \tag{3}$$

Therefore, the RMS of at each centre wavelength of 1/3 octave band, can be approximately expressed as the equivalence RMS of all the wavelength in ever band.

3.2 Filtered rail profile definition

Based on the above simplification, the filtered rail profile at each wavelength range can be expressed as below:

$$F(x) = \sum A_\lambda \cos(\frac{2\pi}{\lambda} x + \theta_\lambda) \tag{4}$$

Where :

$\lambda = \{10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400\}$

A_λ can be calculated in Table 2

Table 2: the Amplitudes calculated based on the limited value of roughness level

Wavelength (mm)	ISO3095:2013 (dB)	RMS(um)	Amplitudes (um)
400	17.1	7.16	10.13
315	15	5.62	7.95
250	13	4.47	6.32
200	11	3.55	5.02
160	9	2.82	3.99
125	7	2.24	3.17
100	4.9	1.76	2.49
80	2.9	1.40	1.98
63	0.9	1.11	1.57
50	-1.1	0.88	1.25
40	-3.2	0.69	0.98
31.5	-5	0.56	0.80
25	-5.6	0.52	0.74
20	-6.2	0.49	0.69
16	-6.8	0.46	0.65
12.5	-7.4	0.43	0.60
10	-8	0.40	0.56

And then, the filtered rail profile at each wavelength range can be figured out and shown from Figure7 to Figure 9.

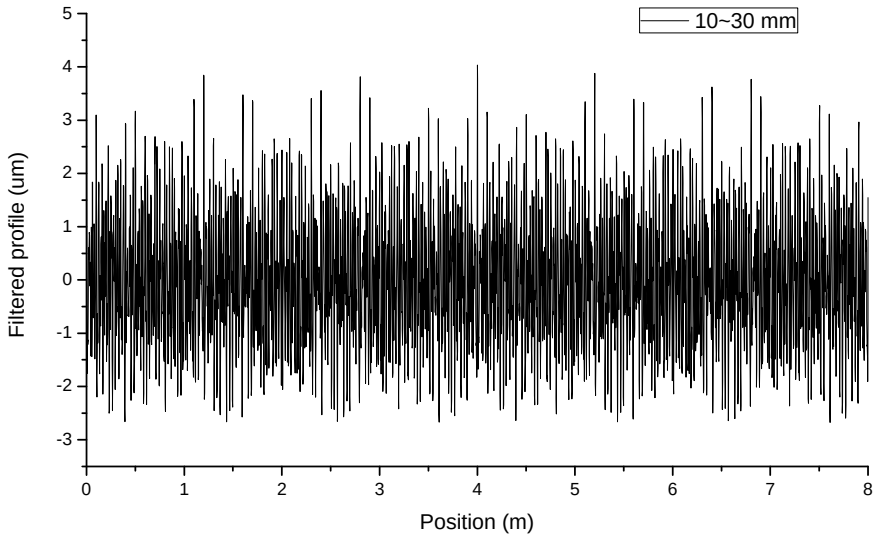

Figure 7: Filtered rail profile in the wavelength range of 10~30mm

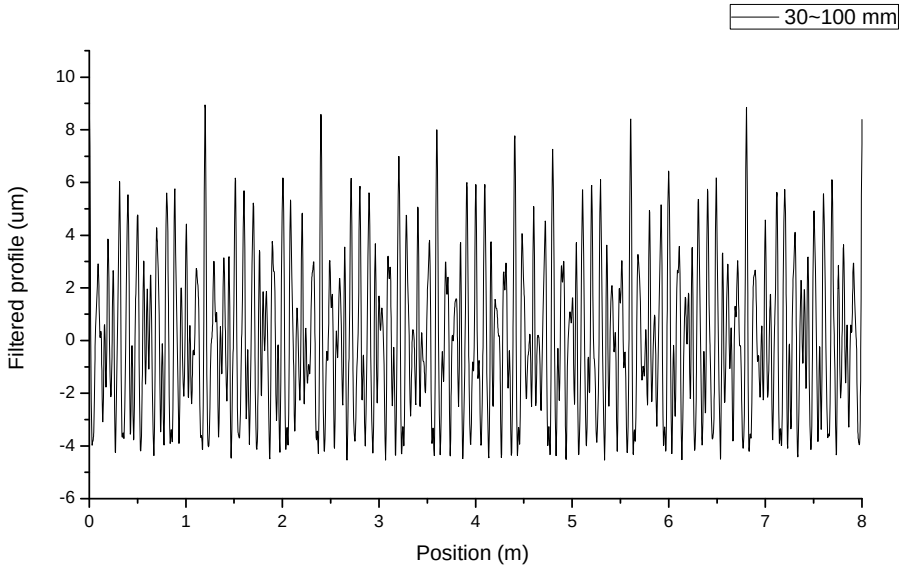

Figure 8: Filtered rail profile in the wavelength range of 30~100mm

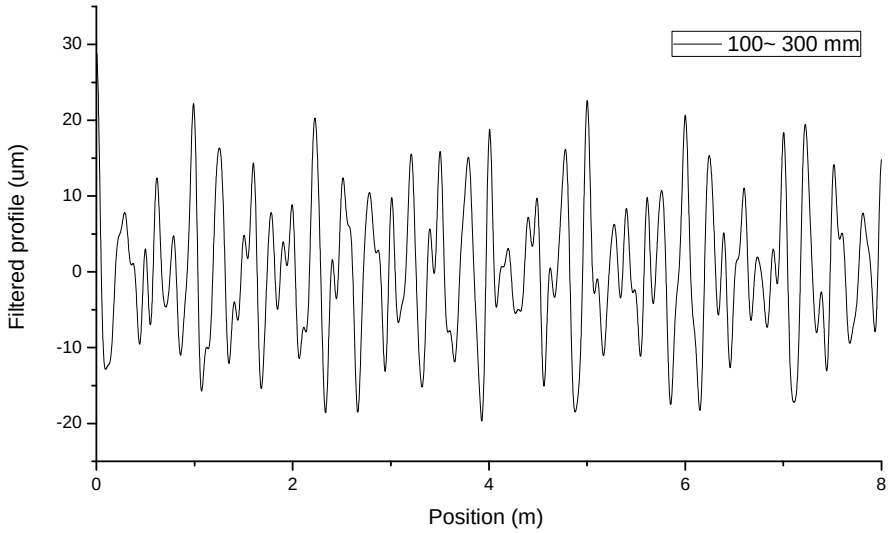

Figure 9: Filtered rail profile in the wavelength range of 100~300mm

After shifting the coordinate to zero and considering 5% allowable exceeding percentage, the recommendation acceptance criteria for peak to peak limits can be list in table 3.

Table 3: The rang of the peak to peak value

Wavelength Range (mm)	10~30	30~100	100~300
Exceeding percentages	5%	5%	5%
Calculated Peak-to-peak value range (um)	-1.84 to 2.07	-3.95 to 5.19	-15.00 to 15.436
Recommendation criteria	± 0,002	± 0,004	± 0,015

4. Validation

After above research , in order to validate the recommendation criteria, the roughness level of each profile were calculated using the Matlab processing provided by EN15610:2009. And the result is shown in Figure 10.

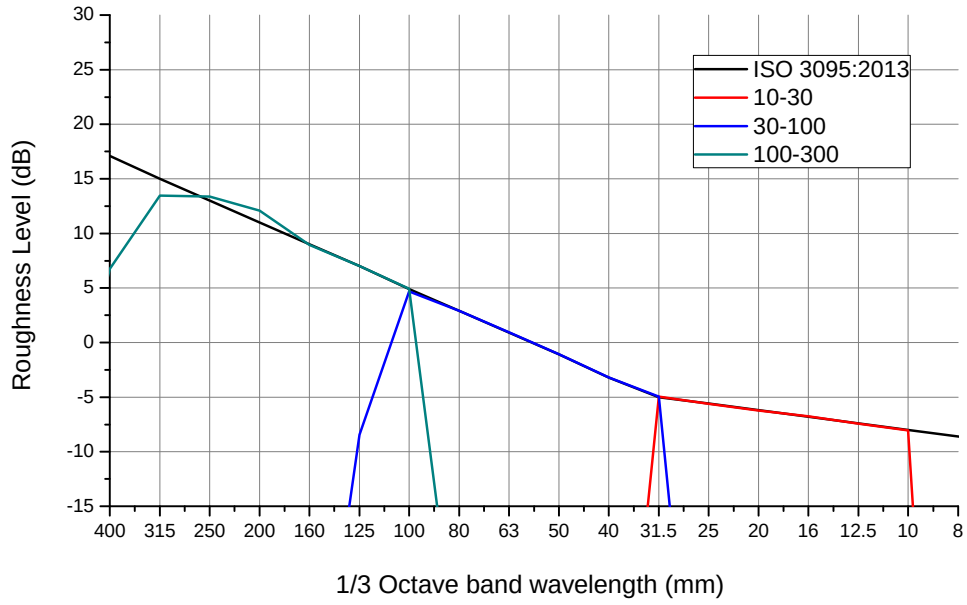

Figure 10: Roughness level calculated according to EN 15610:2009

From Figure 10, although the calculated result in the range of 160~300 mm was effected by some factors such as sampling length ,etc. it is clear that the recommendation criteria can perfectly satisfy the requirement of ISO 3095:2013.

Furthermore , if reprocessing the measurement data collected from Beijing metro mentioned in section 2 of this paper and comparing the results with recommendation criteria (See table4) and Figure 6, it indicated the grinding work is unaccepted for noise reduction.

Table 4: Recommendation acceptance criteria

Wavelength range (mm)	10 to 30	30 to 100	100 to 300
Limit of peak-to-peak values (mm)	± 0,002	± 0,004	± 0,015
Allowable percentages of exceeding	5 %	5 %	5 %
Percentages of exceeding	2%	7%	0%
Grinding quality	Accepted	Unaccepted	Accepted

So far, the gap between ISO 3095:2013 and EN 12132-3:2012 is filled.

5. Summarization

Based on above study, it comes to the following conclusion:

(1) The current standard EN 12132-3:2012 for rail grinding qualification is at too low a level . it is not coincidence with the requirement of ISO 3095:2013 for noise control.

(2) In order to guarantee noise reduction performance in reality, this presented paper recommended a higher level of acceptance criteria to qualify the acoustic grinding work.

Acknowledgements

This work was under the support of Beijing Public Finance (No. PXM2016_178304_000011) and the Postdoctal Program Funds (2016ZZ-83) and the young core personal project of Beijing Academy of Science and Technology: Research of construction noise prediction method on the base of noise map (2016).

REFERENCES

1 BSI - British Standards Institution，BS EN 13231-3：2006 Railway applications —Track — Acceptance of works —Part 3: Acceptance of rail grinding, milling and planning work in track[S].(2006)

2 BSI - British Standards Institution，DIN BS EN 13231-3：2012 Railway applica-tions —Track — Acceptance of works —Part 3: Acceptance of rail grinding, milling and planning work in track[S].(2012)

3 S.L Grassie. *Controlling irregularities in rail to reduce noise[J]*. (2010)

4 IRJ April (2010) UIC/SBB Report ,*Rail Dampers, Acoustic Rail Grinding, Low Height Noise Barriers A report on the state of the art*, Bern . [Online.]available: http://www.uic.org/spip.php?article3027 (2012)

5 B. S. Institution. DIN EN ISO3095:2013- Railway applications —Acoustics —Measurement of noise emitted by Railbound vehicles [S]. (2013)

6 S. L. Grassie, M. J. Saxon, J. D. Smith. Measurement of Longitudinal Rail Irregularities and Criteria for Acceptable Grinding[J]. J Sound Vib, 227(5):949-964.(1999)

7 B. S. Institution. BS EN 15610：2009 Railway applications— Noise emission— Rail roughness measurement related to rolling noise generation[S]. (2009)