# Acoustic Specification of Composite Brake-Blocks for Railway vehicles

Fabien Létourneaux
Innovation Directorate, Systra, Paris, France.

Fabrice Aubin
Rolling Stock Engineering department, SNCF, France.

**Summary**

The reduction of the rolling noise produced by freight wagons is one of the major challenges of the railway sector to develop the freight traffic. In that context, the development of new types of brake blocks (made of composite material) which tend to smooth the wheel tread and then to drastically reduce the rolling noise excitation have been developed. This paper presents an acoustic acceptance procedure which is to be included within the general approval procedure of these composite brake blocks issued by UIC (UIC leaflet 541-4) currently under revision.

The originality of the procedure is that it only requires the measurement of wheel roughness and make use of a virtual TSI NOISE compliant pass-by test to derive a relevant acceptance criterion. Input data (wheel and rail roughness, pass-by noise) coming from a TSI compliant reference test case measured within the frame of the NICOBB project are used to carry out the calculation step. It results in a very simple procedure, which does not require any specific acoustic expertise but is nevertheless enough reliable and accurate to sort out the noisy and quiet brake blocks..

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## 1. Introduction

The reduction of the rolling noise produced by freight wagons is one of the major challenges of the railway sector to develop the freight traffic. In that context, the development of new types of brake blocks (made of composite material) which tend to smooth the wheel tread and then to drastically reduce the rolling noise excitation have been developed. As these new types of brake blocks are now available both for new vehicles (K-blocks) but also more recently for retrofitted ones (mainly LL-blocks) the European Commission have decided to set stringent pass-by noise limits in the EU regulation (TSI NOISE [1]) in order to ban the use of noisy cast iron blocks and then to enhance the environmental friendliness of the railway lines throughout Europe. For new vehicles, the acoustic assessment process is straightforward as it requires a full acoustic acceptance test of the vehicle, but for retrofitted vehicles, the TSI NOISE state that once equipped with composite brake blocks and when no noise sources are added, the pass-by acoustic requirements are assumed to be complied with. This latter statement may be considered as a weak point as there is no guarantee that the new blocks implemented are actually quiet: the acceptance procedure of the component "composite blocks", addressed in the UIC leaflet 541-4 [2], currently do not specify any acoustic requirement. A noise acceptance procedure of composite blocks is then proposed to guarantee the noise performance of the product.

## 2. Objectives

The main drivers that guided the development of the procedure are the following:

a. Guarantee the pass-by noise performance of freight vehicles retrofitted with composite brake-blocks:
    - through a "component-based" noise assessment procedure of brake blocks
    - which do not replace the TSI NOISE type test of whole vehicles
b. The procedure should be "affordable", i.e.:
    - Do not require a full pass-by noise test campaign compliant with TSI requirements

  - might be embedded as far as possible in the certification process of the new composite brake-blocks

c. It should remain simple to foster its acceptability and implementation: a single index as output should be preferred.

## 3. Scope of the procedure

This procedure aims at characterizing the acoustic properties of railway freight vehicles' tread-brake blocks associated with rolling noise and define an acceptance criterion.

It is applicable to:
a. the assessment of the rolling noise produced during pass-by at constant speed
b. brake-blocks of freight wagons

It is not applicable to:
a. the assessment of the noise produced during braking events (squeal noise)
b. brake-blocks of powered vehicles and coaches.

## 4. Principle of the procedure

The procedure comprises 3 steps:
a. It first relies on the ***measurement of wheel acoustic roughnesses*** which are representative of the brake block to be assessed. It is here intend to take advantage of the in-service brake test campaigns.
b. These wheel acoustic roughnesses are then used to ***derive a Single Index*** which aims at comparing the wheel roughness of the new brake blocks to a reference wheel roughness.
c. Last, the ***compliance of the new brake block is examined***, based on the sign of this Single Index

## 5. Measurement of wheel acoustic roughness representative of the new brake-block

### 5.1. Representativeness of the wheel treads

The representativeness of the wheel roughness measured is a key factor of the assessment procedure. It relies both on the selection of a statistically valid sample of wheels and on a suitable conditioning of the treads.

Sample of wheels: the brake-blocks to be assessed shall equip a minimum number of 2 freight wagons and at least 4 wheelsets shall be braked with that blocks.

Wheel tread conditioning: the freight vehicles shall be in its normal operating conditions and shall have run in normal traffic at least 15000 km on track with normal traffic without any wheel reprofiling. The wheel treads shall be as free as possible from irregularities, such as flats. In addition, the block/tread pair shall be in a run-in condition where block and tread have bedded in sufficiently. Photos of on one hand the wheel tread and on the other hand the block should be provided to prove the correct surface conditioning (see figure 1)

Figure 1.photo of a conditioned brake-block

### 5.2. Wheel roughness measurement procedure

There is no published standard specifying the wheel roughness measurement procedure. However this topic is currently in progress at CEN level in the frame of the revision of the standard EN15610 [3] and a first project of the revised standard should be issued by the end of 2015. Meanwhile, it is proposed to comply with the latest specification achieved within the ACOUTRAIN EU FP7 project and fully described in a public report [4].

Figure 2.example of wheel roughness measurement device

The measurement procedure requires the wheel to be jacked of the rail to allow free rotation, to apply radially sensors against the treads and to rotate the wheel in order to acquire digitized records of the wheel roughness over a circumference length (see figures 2 & 3). A spatial Fourier transform of each record and an averaging process are then applied to derive a representative one-third octave wavelength wheel roughness spectrum $\widetilde{L}_{r,wheel}^{new}(\lambda)$.

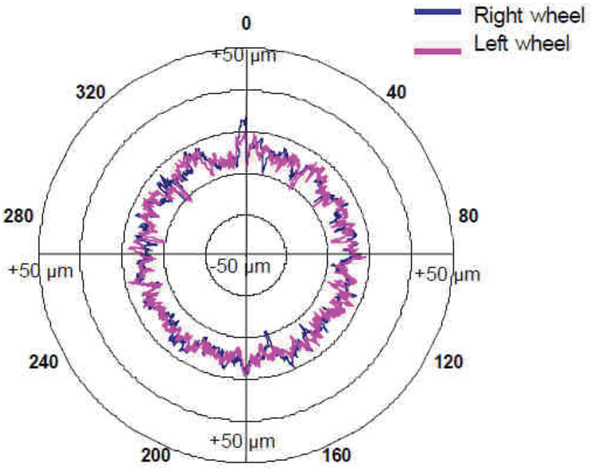


Figure 3.example of wheel roughness measurement result (spatial data)

## 6. Reference TSI NOI compliant test case

### 6.1. Description of the test

The procedure relies on results from a preexisting reference pass-by noise test campaign, compliant with the TSI NOISE and carried out within the UIC NICOBB project [5].

Figure 3.Train and site of the reference test campaign

The track section was a reference track (acoustic rail roughness and Track Decay Rates compliant with the TSI NOI specifications)
During the test the train have run at constant speed at 80km/h and was composed of 23.86m long 4-axle sliding-wall wagons (type Habbiins 14) taken from the traffic and equipped with LL blocks (IB116*).
The following data have been acquired:

- One-third octave frequency spectrum of the measured pass-by noise level at 80km/h $L_{pAeq,Tp}^{ref}(f_i)$
- One-third octave wavelength spectrum of the acoustic rail roughness of the test track section $\widetilde{L}_r^{rail,ref}(\lambda)$
- Representative one-third octave wavelength wheel roughness spectrum of the reference wagons $\widetilde{L}_r^{wheel,ref}(\lambda)$

### 6.2. Specific processing to derive input data for the procedure

A specific processing is made on the measured spectra to derive a transfer function $\widetilde{L}_H^{ref}$ later called "weighting function". This processing make use of the acoustic rail and wheel roughnesses, the noise levels and the TSI NOI limit value corresponding to the vehicle under test.

Table I. Results of the reference test campaign used as inputs to the procedure

| *Wavelength [m]* | $\widetilde{L}_{r,rail}^{ref}$ *[dB re 1micron]* | $\widetilde{L}_H^{ref}$ *[dB re 1micron]* |
|---|---|---|
| 0,00315 | -17,9 | -19,2 |
| 0,004 | -16,2 | -16,5 |
| 0,005 | -15,5 | -13,1 |
| 0,0063 | -14,4 | -9,5 |
| 0,008 | -13,3 | -8,0 |
| 0,01 | -13,1 | -6,8 |
| 0,0125 | -12,8 | -5,1 |
| 0,016 | -12,4 | -4,5 |
| 0,02 | -10,9 | -4,4 |
| 0,025 | -11,1 | -6,5 |
| 0,0315 | -10,5 | -9,0 |
| 0,04 | -9,8 | -11,1 |
| 0,05 | -4,8 | -15,5 |
| 0,063 | -5,9 | -17,5 |
| 0,08 | -5,6 | -22,3 |
| 0,1 | -0,5 | -30,3 |
| 0,125 | 2,4 | -31,4 |
| 0,16 | 4,8 | -32,9 |
| 0,2 | 2,4 | -32,2 |

- First, the noise spectrum is transformed into the wavelength domain, using the train speed: $\widetilde{L}^{ref}_{pAeq,Tp}(\lambda_i) \rightarrow \widetilde{L}^{ref}_{pAeq,Tp}(f_i)$
- Then the combined frequency roughness spectrum corresponding to the reference wagon is calculated

$$\widetilde{L}^{comb,ref}_{r}(\lambda_i) = \widetilde{L}^{wheel,ref}_{r}(\lambda_i) \oplus \widetilde{L}^{rail,ref}_{r}(\lambda_i)$$

where $A \oplus B = 10 \cdot \log_{10}\left(10^{A/10} + 10^{B/10}\right)$

- Next the transfer function between noise and roughness of the reference case in the wavelength domain is derived

$$\widetilde{L}^{ref}_{H}(\lambda_i) = \widetilde{L}^{ref}_{pAeq,Tp}(\lambda_i) - \widetilde{L}^{comb,ref}_{r}(\lambda_i)$$

- Last, this transfer function is normalized by evenly substracting the TSI NOISE limit value in all the wavelength bands.

## 7. Calculation of the Single Index of Wheel Roughness

### 7.1. Input data

Considering the following data derived from the reference test case:

- One-third octave f of the acoustic rail roughness of the test track section $\widetilde{L}^{ref}_{r,rail}(\lambda)$
- One-third octave weighting spectrum $\widetilde{L}^{ref}_{H}(\lambda)$

And the one-third octave wavelength wheel roughness spectrum $\widetilde{L}^{new}_{r,wheel}(\lambda)$ representative of the new brake-blocks, the following procedure shall apply:

### 7.2. Generate the weighted combined roughness spectrum corresponding to the new brake blocks

$$\widetilde{L}^{comb,weighted}_{r}(\lambda_i) = \widetilde{L}^{ref}_{H}(\lambda_i) + \left[\widetilde{L}^{wheel,new}_{r}(\lambda_i) \oplus \widetilde{L}^{rail,ref}_{r}(\lambda_i)\right]$$

### 7.3. Calculate a Single Index of Wheel Roughness corresponding to the new brake-blocks

$$Index = 10 \cdot \log\left(\sum_i 10^{0.1 \cdot \widetilde{L}^{comb,weighted}_{r}(\lambda_i)}\right)$$

The Single Index is calculated by summing all the wavelength bands of the weighted combined roughness spectrum.

The result is then rounded to the nearest integer

### 7.4. Assess the compliance of the new block

The new block is then deemed to be acoustically compliant if *Index* ≤0

## 8. Validation of the procedure on available data

The procedure have been applied to different set of available data coming from measurement campaigns carried out at national and European levels (UIC RP16, UICRP32, EuropeTrain, ….). Results are presented in figure 4. In each campaign, the train was composed of freight wagons, some of them equipped with composite brake-blocks (quiet) and the remaining with cast iron brake-blocks (noisy). For all pass-by, the noise levels emitted at 7,5m from the track centerline by the different types of wagons are measured and then normalized:

- To the same value of Axle Per Length (APL) in order to make possible a relevant comparison between different types of wagons, as the density of sources highly influences the pass-by noise levels
- to the noise produced by the wagons equipped with cast iron brake-blocks of the same campaign in order to limit the influence of the track in the comparison between campaigns.

The comparison between the normalized measured noise levels and the calculated single index of wheel roughness shows that the single index allows to consistently sort out the vehicles equipped with the noisy brake-blocks and the quiet ones without any noise measurement. Moreover, the Kombi blocks (Europetrain campaign), which are made of composite material but also contain some cast iron inclusions are identified as not compliant as expected. But the figure 4 also highlights a significant spread between results of the same type of brake-blocks among the different campaigns (see for instance LL-C952-1 and Cosid952 or results of cast iron blocks). This spread is probably due to a lack of control of the test conditions which are then not similar between campaigns: track conditions, measurement procedure of wheel roughness, mileage of the wheels (wheel conditioning). This issue should however be addressed carefully in order to achieve a robust and accurate acoustic acceptance procedure of brake-blocks based on the single index of wheel roughness.

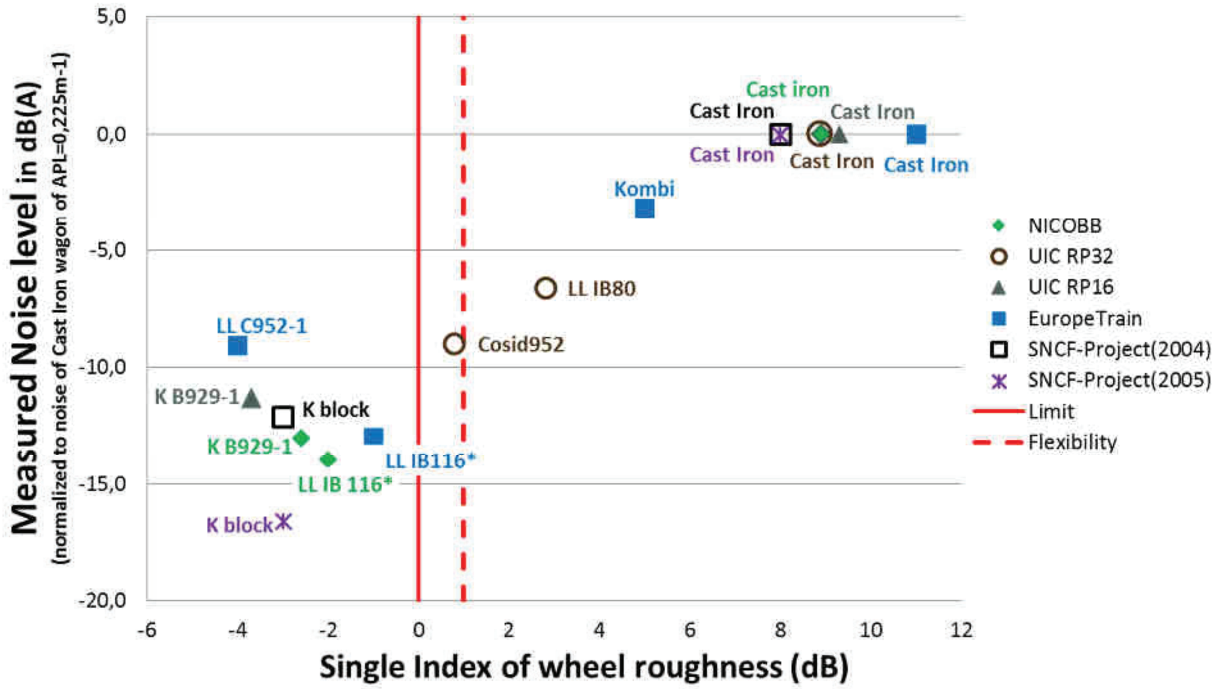


Figure 4. Validation of the relevance of the Single index of wheel roughness against measured noise levels

## 9. Conclusions

A noise acceptance procedure has been developed and proposed in the frame of the certification process of composite brake-blocks. This procedure aims at objectifying the noise performance of these composite products which are assumed to be quiet in the context of the European acceptance process of retrofitted freight vehicles (TSI NOISE).
This procedure is solely based on wheel roughness measurements and could easily be embedded in the program of brake tests.
The implementation of this acoustic procedure in the certification process of composite brake-blocks is in progress through the revision of the UIC leaflet 541-4 currently handled by the brake expert group UIC B126-13. In parallel, it is envisaged to further investigate the reliability, accuracy, and applicability of the procedure in a dedicated project to be submitted to UIC.

## References

[1] TSI NOISE - Commission Regulation (EU) No 1304/2014 of 26 November 2014

[2] UIC541-4 OR, Brakes – brakes with composition brake blocks – general conditions for certification of composite brake blocks

[3] EN 15610, Railway applications — Noise emission — Rail roughness measurement related to noise generation

[4] Proposed analysis method for wheel roughness, deliverable D2.4 of the Acoutrain EU FP7 project, D. Thompson, ISVR.

[5] UIC project NICOBB – WP2 Field tests: Noise measurements of freight wagons equipped with K-, -LL- and CI- blocks (Week 38/2007). DB SystemtechnikTest report , june 2008.. Reference 07-P-5636-TZF12.1-V3