Brake noise measurements on mixed freight trains with composite brake blocks

Erwin Jansen[a], Michael Dittrich[a] and Erik Sikma[b]

[a]TNO Science and Industry, PO Box 155, 2600 AD Delft, Netherlands
[b]Lloyd's Register Rail Europe B.V., PO Box 2016, 3500 GA Utrecht, Netherlands
erwin.jansen@tno.nl

Brake noise is known to be a major contributor to the total sound emission of railway yards and areas near stations. It has been established that composite brake blocks reduce rolling noise, but it is not known if this is also the case for braking noise. Therefore, in order to investigate this, noise measurements were conducted on mixed freight trains according to the applicable protocols. Measurements were conducted on trains slowing down from a speed of 30 km/h to standstill and on trains passing-by with brakes applied. Some composite brake blocks showed a considerable reduction of both braking pass-by levels and peak noise levels. Results are presented. If squeal noise is absent, braking noise of most considered brake blocks show a speed dependency similar to that for rolling noise.

1 Introduction

In the Netherlands, the noise emission of railway yards and areas near stations, which are often located in urban areas, is a source of disturbance. The noise emission of railway yards is legislated in terms of maximum allowable equivalent sound pressure levels at the façade of dwellings, and the rise speed of peak noise levels. Brake noise is known to be a major contributor to the total sound emission of shunting yards, in particular from trains with cast-iron (GG) block brakes. Brake noise has a broad band frequency content, sometimes containing high frequency tonal components, squeal noise, induced by stick-slip excitation of the wheel. This can be the case for both trains braking to standstill and braking at speed.

Within the scope of the Dutch Innovation Programme on Noise Reduction, the rolling noise reducing effect of alternative composite block brakes, such as LL and K blocks, was successfully demonstrated [1]. Additionally, the effect of composite brake blocks on braking noise was investigated. For this purpose, TNO conducted brake noise measurements on various freight wagon types equipped with cast-iron, K-block and LL-blocks, which brake the wheels on the tread. The objective of the measurements was to quantify the peak noise and equivalent noise levels during braking to standstill and braking at speed, with the various types of brake blocks. Standard measurement protocols were applied for this purpose. Also comparisons with unbraked pass-by levels were made.

Type designation	L [m]	# axles	APL	Brake Blocks				
				GG	LL			K
					Cosid 952	Jurid 777	Becorit IB116*	Cosid 810
Laeks 	27	3	0.1	x	x	x	-	-
Shimms 	12	4	0.3	x	-	-	-	x
Sgns 	19.64	4	0.2	x	x	x	x	x
Habills 	24.13	4	0.17	x	-	-	-	-
Tapps** 	15.45	4	0.26	-	-	-	-	x

** with and without wheel dampers installed

Table 1 Characteristics of the wagon types. APL indicates number of axles per unit wagon length.

2 Wagon type/brake-block combinations

The test trains consisted in total of five types of freight wagons, equipped with various brake blocks. The tested wagon types and their properties are listed in table 1. The wagon groups were assembled into four different test trains. In each wagon group at least three wagons were present.

The wagons were retrofitted with the following brake blocks:

LL-blocks: Cosid 952 en Jurid 777 (material: sintered composite)

Becorit IB116* (material: organic composite with added rubber)

K-blocks: Cosid 810 (material: organic composite)

For some wagon types, conventional cast-iron block braked wagons were added for reference purposes.

Some of the Tapps wagons were also equipped with wheel dampers of Schrey & Veit, so-called sandwich dampers. These are block-shaped dampers, made of alternate layers of polymer and steel that dissipate the wheel vibrations, fitted to the interior of the wheel rim.

3 Measurements

Measurements were made according to two applicable protocols:

- Noise Emission Measurement Protocol for Rolling Stock as Operated in Railway Yards [2]. This protocol was applied for braking to standstill;
- Dutch Regulation on Emission Measurement Methods for Railway Vehicles, hereafter referred to as 'TR' [3]. This protocol was applied for braking at speed.

The measurements were conducted on the TSI compliant track in Susteren and on an ISO compliant track near Bergen op Zoom, both in the Netherlands.

3.1 Braking to standstill

According to the applicable protocol [2] the following procedure is to be followed. Two microphone positions are to be used: one at the front of the vehicle where it begins to apply the brakes and one 20 m further along the track in the direction of motion. The microphones are at 7,5 m from the track centreline and at a height of 1,2 m above the rail surface. The vehicle arrives at a speed of 30 km/h and starts a normal service braking down to standstill. The measurement begins at each microphone at the moment that the front of the vehicle passes the microphone and ends either when the back of the vehicle has passed the microphone or if the vehicle has already come to a standstill. The measurements are performed 3 times in one direction and 3 times in the other direction, starting from the second microphone. For the equivalent sound pressure level $L_{pAeq,tp}$ the energy average over the two microphone positions is taken. After this the arithmetic average over the 6 braking runs is made. The maximum level L_{pAFmax} is the highest of the two positions.

Due to practical limitations concerning the train length and the fact that the trains consisted of mixed wagon types, some deviations from the protocol have been made. Three microphones were installed along the measurement track, see figure 1. The distance between the microphones was selected such that the centre wagon of a wagon group came to standstill at a microphone. The centre wagon was taken to minimize the influence of adjacent wagons. A marker indicated the start of the braking, so as to stop the train at the right position, see figure 2. The brake path of the test trains with a speed of 30 km/h, with a length of approximately 500 m, was about 100 m. At least three measurements per test train were performed.

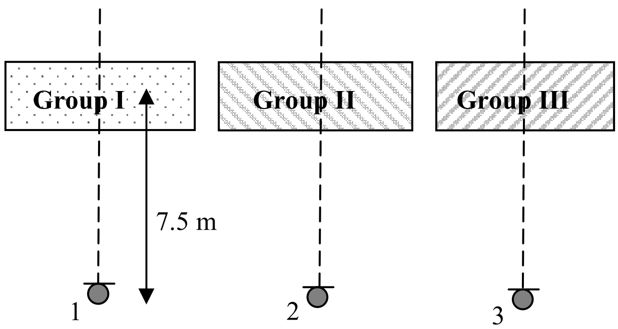

Fig.1 Schematical overview of the measurement set-up. The microphones are located at 7.5 m from the centre of the track, 1.2 m above the ground level.

Fig.2 Photo of the test train passing the measurement site. Here, the locomotive is hauling K-block braked Shimms wagons and Tapps wagons, some of which were equipped with wheel dampers.

3.2 Braking at speed

According to the TR [3], the test train should start braking with maximum brake force 20 m before a single microphone. The measurement stops when the train has passed by. The measurements are to be taken at: 25, 50, 75, 100 and 120 km/h.

Again, some practical issues had to be overcome. Due to the train lengths, low speed pass-bys were not possible since the trains would have come to a full stop prior to having passed the microphone. Also, due to the train length it takes some time for the brake pressure to build up. The trains had to start braking 400 m before the microphone to guarantee a uniform brake pressure over the train length. It was not possible to obtain 120 km/h as a braking speed. In this case the start speed would have been too high. Therefore, the runs started with 120 km/h and 100 km/h. This resulted in a braking start speed at the microphone of about 100 km/h, decelerating to 75 km/h, and 75 km/h decelerating to 50 km/h.

Using the signal of an accelerometer installed underneath the rail and the wagon lengths, the average pass-by speed per wagon group of the decelerating train was assessed. By repeating the measurement in reverse driving direction, approximately equal speed ranges could be obtained for each wagon group.

4 Results

4.1 Braking to standstill

Protocol [2] covers both peak noise levels (L_{pAFmax}) and equivalent noise levels ($L_{pAeq,tp}$). This study is focused on the peak noise levels, as shown in table 2 for braking from 30 km/h to standstill. As not all measurements fully complied with the standstill positions as indicated in figure 1, some measurements were rejected.

Wagon type	Laeks			Shimms		Sgns				Habills	Tapps	
Brake block	LL Cosid 952	LL Jurid 777	GG	GG	K Cosid 810	GG	LL Cosid 952	LL Jurid	LL Becorit	GG	K Cosid 810	K+ Cosid 810
Measurement 1	99	90	104	-	90	99	98	101	73	108	82	88
Measurement 2	102	99	108	-	89	101	98	99	82	108	84	84
Measurement 3	103	102	107	-	-	98	-	-	-	106	82	84
Mean	101	97	106	-	90	99	98	100	78	107	83	85

Table 2 Peak noise levels ($L_{pA,max,F}$) for braking from 30 km/h to standstill in dB(A). "+" indicates that wheel dampers were installed.'GG' indicates cast-iron.

Peak noise levels for cast-iron block braked wagons varied between 99 and 107 dB(A), including tonal squeal noise, indicated by the tonal component in figure 3. This peak is probably caused by longitudinal slip-stick excitation of the wheels. Peak noise levels for wagons braked with sintered LL-blocks varied between 97 and 101 dB(A), occasionally including squeal noise. Peak noise levels for K-block braked wagons varied between 83 and 90 dB(A), and do not include squeal noise. It is remarkable that the noise levels for the Tapps wagons with wheel dampers were about 2 dB(A) higher than the wagons without wheel dampers. This increase is broadband for frequencies from 250 Hz to 4 kHz. For rolling noise, on the other hand, the wheel dampers showed a decrease of the pass-by level of about 2 dB(A) [1]. During braking, different wheel modes are excited than for rolling noise. Apparently, the wheel dampers do not damp these vibration modes.

The lowest peak noise levels were found for the Sgns wagons with Becorit block brakes (an organic LL-block). Also, the peak noise levels were considerably lower than for other type of sintered LL-blocks, with peak noise levels about equal to those of cast-iron block braked wagons. This can be explained by the sound spectra, as shown in figure 3.

In the spectra for cast-iron and LL block braked wagons, high frequency tonal components can be observed at 5 kHz.

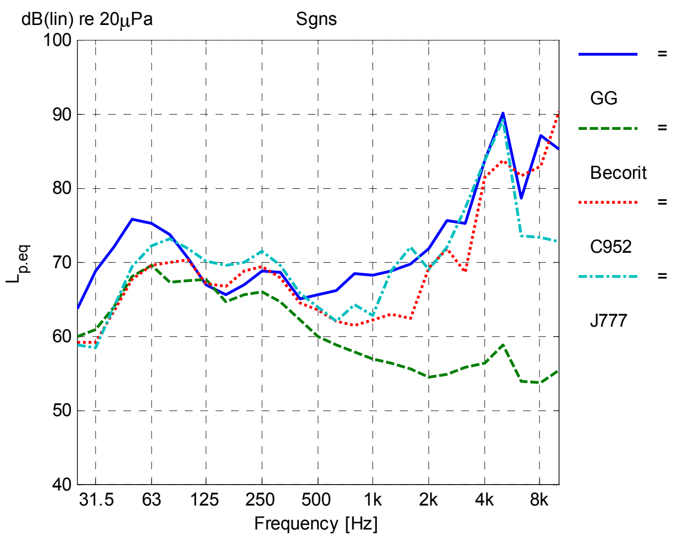

Fig.3 Equivalent noise level spectra of the braking process from 30 km/h to standstill for Sgns wagons with various brake block types.

However, for the Becorit blocks this is not the case. These composite blocks contain a certain amount of rubber. Apparently, this affects the friction characteristics such that squeal is avoided. This results in peak noise levels of more than 20 dB lower.

4.2 Braking at speed

Figure 4 gives an overview of the measured pass-by levels during braking at speed for the various wagon types and brake blocks. Cast-iron block braked wagons have the highest pass-by levels. The lowest pass-by levels are found for the Becorit and K-block braked wagons.

Apart from the Tapps wagons with K-blocks, for each wagon type/brake block combination a straight trend line can be fitted through the measurement points. Some measurement points clearly deviate from the trend line, e.g. the pass-by level for the Sgns wagon with C952 brake blocks at 58 km/h. For this particular pass-by, squeal noise occurred, whereas for the other pass-bys it did not, see figure 5. Least square fits were made, to assess the speed dependency. The pass-bys for which squeal occurred were not taken into account.

Most sound spectra are similar to rolling noise and follow the 30lg(v) relationship. Apparently, in analogy to rolling noise, the roughness excitation mechanism governs the sound generation in the brake block contact area.

For all considered wagon types also the pass-by levels were measured without braking at various train speeds, see [1]. By comparing the braking and non-braking results, the *brake noise gain* was assessed per wagon type, see table 3. K-blocks tend to have the lowest brake gain. The brake noise gain ranges for LL-blocks and cast-iron blocks overlap.

In figure 6 a comparison between pass-by level spectra of Sgns wagons with cast-iron blocks and LL-blocks with and without braking at speed (just rolling noise) is shown. The brake noise gain is a broadband increase of the pass-by levels. For the LL-block it is a combination of a broadband and tonal increase due to squeal noise.

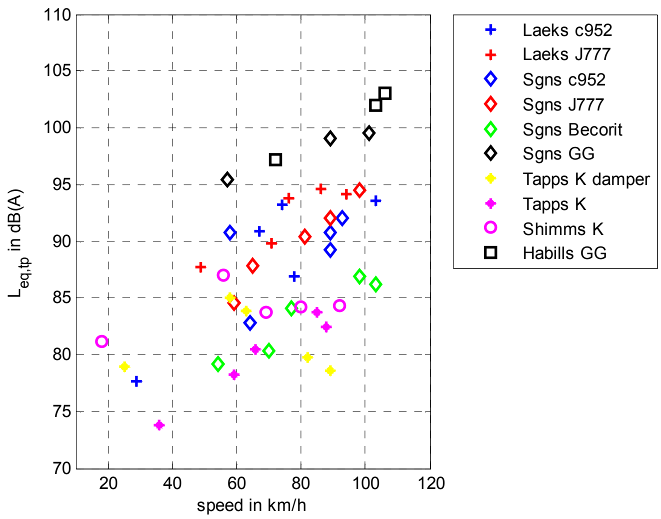

Fig. 4 Pass-by levels for braking at speed for various wagon types with various brake blocks. Each wagon type is indicated by a unique symbol. Each brake block is indicated by a unique colour. In order to be able to compare the pass-by levels of the wagon types, all pass-by levels are converted to an axle density of 0,15.

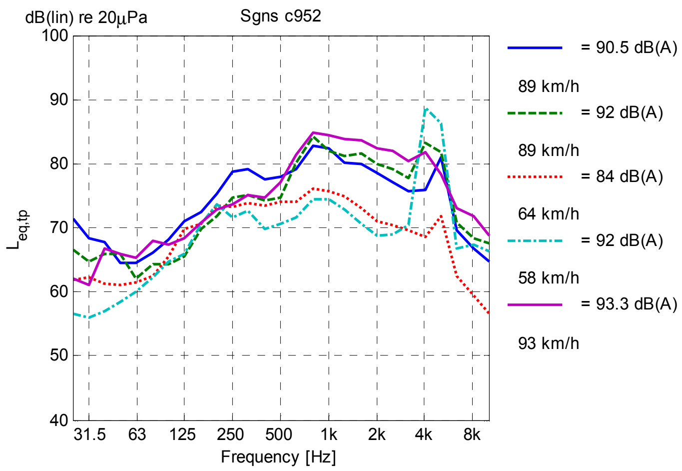

Fig. 5 Pass-by levels of braking at speed for Sgns wagons with various brake block types at various pass-by speeds. Squeal occurs at a speed of 58 km/h.

Type	Brake block	Δbrake in dB(A)
Laeks	LL (C952)	8
	LL (J777)	9
Sgns	LL (C952)	7
	LL (J777)	8
	LL (Becorit)	4
	GG	6
Shimms	K (Cosid)	3
Tapps	K (Cosid)	4
	K+ (Cosid)	5
Habills	GG	7

Table 3 Brake noise gains (Δbrake) of the pass-by levels in dB(A) at 80 km/h. '+' indicates with wheel dampers.

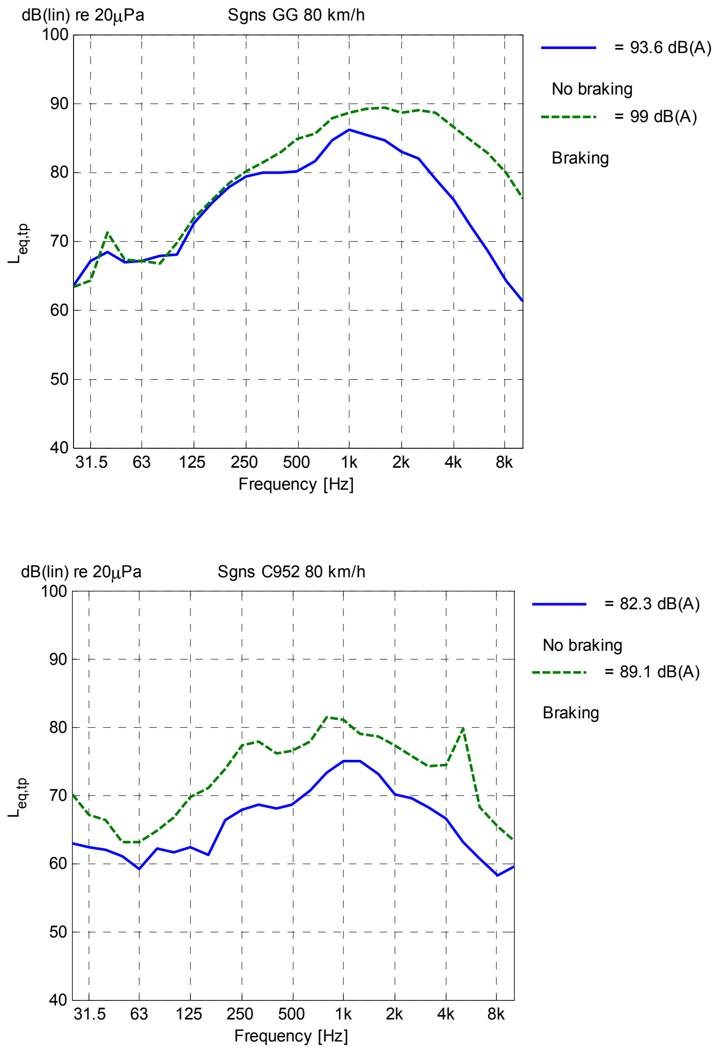

Fig. 6 Pass-by levels with and without braking at speed for Sgns wagons with cast-iron blocks (top) and LL blocks (bottom) at a speed of 80 km/h.

5 Conclusions

Brake noise measurements were conducted on several freight wagon types with various composite and cast-iron brake blocks, for both braking to standstill and braking at speed. It was found that composite brake blocks not only reduce rolling noise but also brake noise.

Noise generated by braking to standstill was quantified in terms of peak noise levels, which can be considerably decreased by applying brake blocks that have friction characteristics that prevent squeal. Composite brake blocks with added rubber content produced the lowest peak noise levels at 7,5 m of about 78 dB(A). Other included types of LL blocks did not prevent squeal, but still resulted in lower noise levels compared to conventional cast-iron block brakes.

Noise generated by braking at speed was quantified in terms of equivalent pass-by levels as a function of speed. Cast-iron block braked wheels have the highest levels for braking at speed. The lowest pass-by levels were found for the K and LL (with added rubber) block braked wagons. If squeal is not present, most of the considered wagon type/ brake block combinations follow the 30lg(v) relationship for rolling noise. The brake noise gain was found to be a broadband increase of the rolling noise pass-by levels, occasionally accompanied by a tonal squeal noise component.

Whereas the studied wheel dampers have a noise reducing effect on rolling noise, the noise levels for both braking to standstill and braking at speed were slightly increased.

Practical experience with applicable measurement protocols for braking noise was gained. Some practical issues had to be resolved, due to the composition of the mixed trains and the train lengths.

Acknowledgments

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