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Methods and results of field testing of a retrofitted freight train with composite brake blocks

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Abstract

Legal limits will be applied to pass-by noise of railway vehicles in Switzerland. As a consequence, existing freight wagons have to be retrofitted. The exchange of cast iron brake blocks by composite ones is a well-known low-cost measure to reduce pass-by noise. The Swiss Agency for the Environment (BUWAL) commissioned a measurement campaign in the year 2003 to define the noise limit, test conditions and maintenance procedures for retrofitted freight wagons.

The test was set up in order to allow the control, or at least the knowledge of all relevant parameters concerning track, vehicles, test and boundary conditions. A track section was reconstructed. The test train was arranged with one reference group of wagons with cast iron brake blocks and several groups of wagons with composite brake blocks and different characteristics. As all wagon groups were operated together in one test train, boundary conditions and test parameters were identical for all wagons.

The noise reduction achieved relative to cast iron block braked vehicles was in the expected range. Additionally, it could be observed that standard procedures in infrastructure and freight wagon maintenance do not ensure a sustained noise reduction. Several effects destroy this noise reduction. Measures to ensure a qualified noise reduction sustained for the full lifetime of a freight wagon were identified.

1. Introduction

The pass-by noise will be legally limited for new and existing rolling stock in the near future in Switzerland [1]. Existing rolling stock, whenever operated further, has to be retrofitted. The Swiss Agency for the Environment (BUWAL) commissioned a measurement campaign in the year 2003 to define the noise limit for retrofitted wagons. The limits had to be defined in such a way that wagons with cast iron brake blocks would not comply and therefore disappear. Additionally it had to be ensured, that the limits can be achieved with composite block braked wagons, which is currently the retrofit solution with the best benefit at lowest costs. It had to be avoided that the limit would lead to shifting even more traffic from rail to road. In parallel to the definition of the limit, test conditions had to be defined. The influence of several parameters to the pass-by noise of composite block braked vehicles had to be analysed (length of vehicles, wheel types, bogie types,

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running distance since last reprofiling, type of superstructure, two axle wagons versus bogie wagons, rail roughness, train speed).

The reduced pass-by noise of composite block braked vehicles revealed some effects, which cannot be observed on cast iron block braked vehicles as their high pass by noise masks them. A typical order of magnitude of the loss of noise reduction was assessed. The measures, which are all in the maintenance field, were defined to ensure a sustained noise reduction for retrofitted wagons.

2. Test methodology

2.1. General

It is well known that the challenge for railway noise measurements is not the sound level measurement itself but the knowledge of the conditions. The measurement campaign was set up in such a way that it allowed the control of, or at least the knowledge of, all relevant parameters.

2.2. Test track

On the line section Kerzers-Müntschemier near the Swiss capital of Berne, operated by BLS Lötschbergbahn AG (BLS), a track section with a length of 108 m was replaced by a track according to prEN ISO 3095 [2]. It was equipped with UIC 60 rails, concrete monobloc sleepers, Vossloh K14 fastenings with a Lupolen pad between sleeper and rail with a nominal stiffness of 450 kN/mm. The rail surfaces were ground some weeks before the measurements. The rail roughness as well as the decay rates were measured according to Ref. [2] just before the measurements.

To minimise the risk of unstable running of the vehicles, the gauge was measured and corrected to the nominal value of 1435 mm over a length of 200 m to each side of the measuring section. The line is operated at 125 km/h mainly with passenger trains of different types (74 per day), high-speed trains (4 per day) and some freight trains (typically 4 per day).

The conditions for measurements fulfil the requirements of Ref. [2]. An overview of the test site is presented in Fig. 1. The roughness of the rails is presented in Fig. 2 together with the reference curves of prEN ISO 3095 [2], TSI HS [3] and TSI CR [4].

2.3. Test train

Wagons to be integrated in the test train had to fulfil some requirements. They had to be of types which are widely used and achieve a high annual running distance in Switzerland. The influence of the parameters wheel type, bogie type, vehicle length, running distance since reprofiling and number of axles had to be determined

Fig. 1. Picture of the track section near Kerzers, where the measurements were performed.

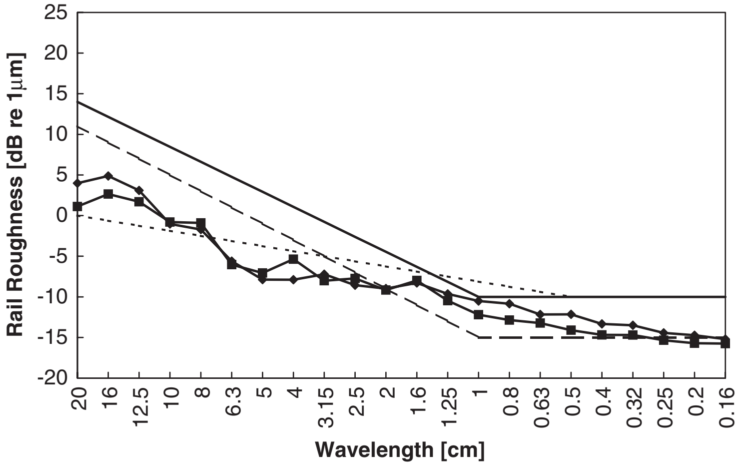

Fig. 2. Rail roughness at the measuring site near Kerzers, compared with the limits as defined in Refs. [2–4]. —◆— measured: right rail, —■— measured: left rail, — prEN ISO 3095 limit, - - - TSI HST limit, — — TSI CR limit.

separately. Therefore, the test train had to be assembled in such a way that, from one wagon type to another one, only one of these parameters changes. Different wagon superstructures had to be tested as well. In this case it was not possible to change only the superstructures without changing any other parameters. As far as possible, wagons, which are already operated with composite brake blocks, were rented for the test train; others had to be modified especially for this measuring campaign (bogie exchange, wheel exchange).

An overview on the parameters and their allocation to the wagon groups is presented in Fig. 3, the details on the parameters can be found in Table 1. Each wagon group consisted of at least three wagons of the same type and condition.

A passenger coach with axle mounted disc brake was placed between the reference group with cast iron brake blocks and the composite block braked wagons to avoid noise from the noisy wagons interfering with the quiet ones. The train was operated by BLS with two low-noise locomotives of type BLS Re465.

2.4. Test conditions

All the wagons were operated in one test train. Therefore, speed, weather, track conditions and boundary conditions were identical for all wagons. Together with the knowledge on track type, roughness, decay rate, history of the wheel running surfaces and the measuring site with ideal conditions it is possible to transfer the results into other situations (like track roughness conditions, speed, …) or to compare them with other measurements with exactly controlled conditions.

One campaign with three runs at 50, 80 and 100 km/h each was executed in the first night and in the following night, the same programme was executed after braking the train three times to a complete stop with a full braking. This was done to see the influence of recent brake applications on pass-by noise.

2.5. Measured and derived quantities

The $L_{pAeq,T}$ according to prEN ISO 3095 [2] was derived from the measured quantity. Additionally, the mean wheel roughness of each wagon group was determined with the indirect method of TNO [5]. As an input, the pass-by analysis software [6] needs rail accelerations and as an output it delivers total roughness. From the directly measured rail roughness, the wheel roughness was determined.

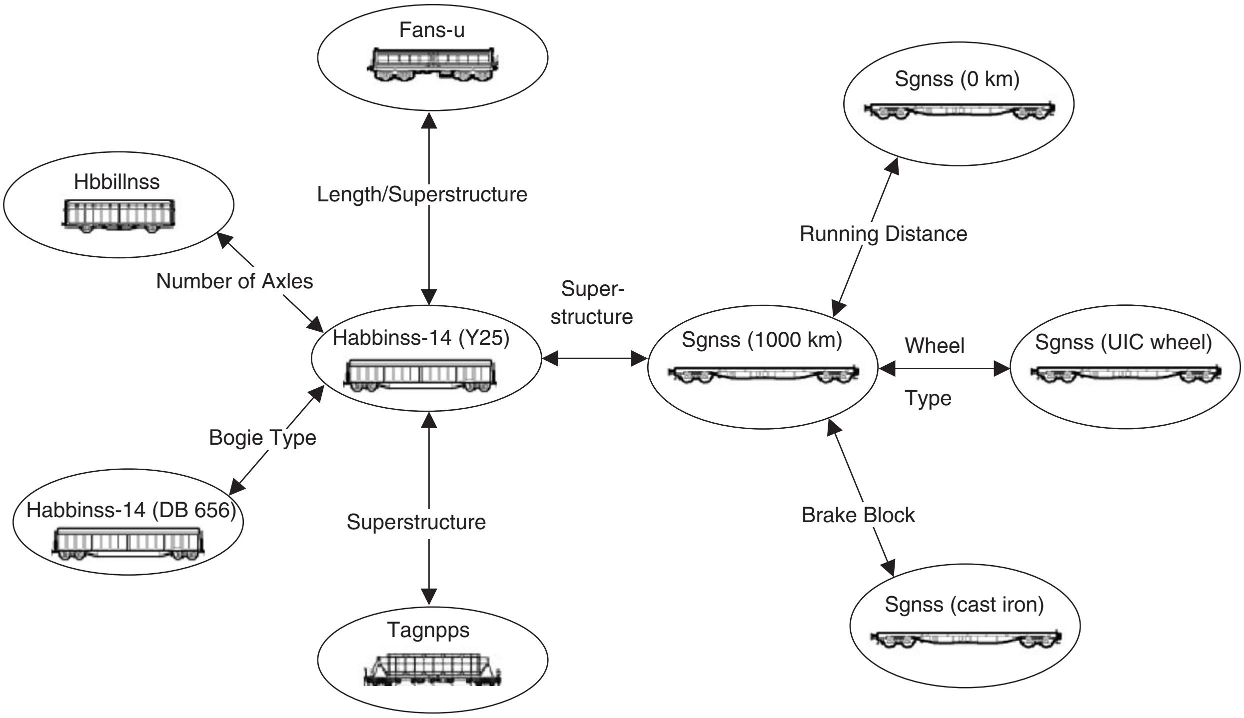

Fig. 3. Overview on the measured wagon types. The arrows show between which wagon groups the influence of a particular parameter was analysed.

Table 1
Configurations of the wagon groups in the test train

	Habbinss-14 (Y25)	Habbinss-14 (DB 656)	Sgnss (UIC wheel)	Tagppns	Sgnss (0 km)	Sgnss (1000 km)	Hbbillnss	Fans-u	Sgnss (cast iron)
Number of wagons	3	3	3	3	4	5	3	3	3
Bogie type	Y25	DB 656	Y25	Y25	Y25	Y25	—	Y25	Y25
Wheel type	Db 11 Sa	Db 11 Sa	UIC Db 10	Db 11 Sa	Db 11 Sa	Db 11 Sa	Db 11 Sa	Db 11 Sa	UIC Db 10
Number of axles	4	4	4	4	4	4	2	4	4
Axles/m	0.22	0.22	0.20	0.20	0.20	0.20	0.13	0.31	0.20
reprofiling	Yes	No	Yes	No	Yes	Yes	No	No	No
Approx. running distance since reprofiling	1000 km	—	1000 km	—	200 km	1200 km	—	—	—

All wagons except the reference group of the Sgnss with cast iron blocks were equipped with composite brake blocks. The wheel type Db 11 Sa is a low stress wheel type; the UIC Db 10 is a wheel with a straight wheel disc.

3. Test results

3.1. Noise reduction

Fig. 4 shows the mean values of the pass by noise levels measured according to prEN ISO 3095 [2] at 7.5 m distance and 1.2 m above rail head level. A typical noise reduction of 12–14 dB for composite brake blocks

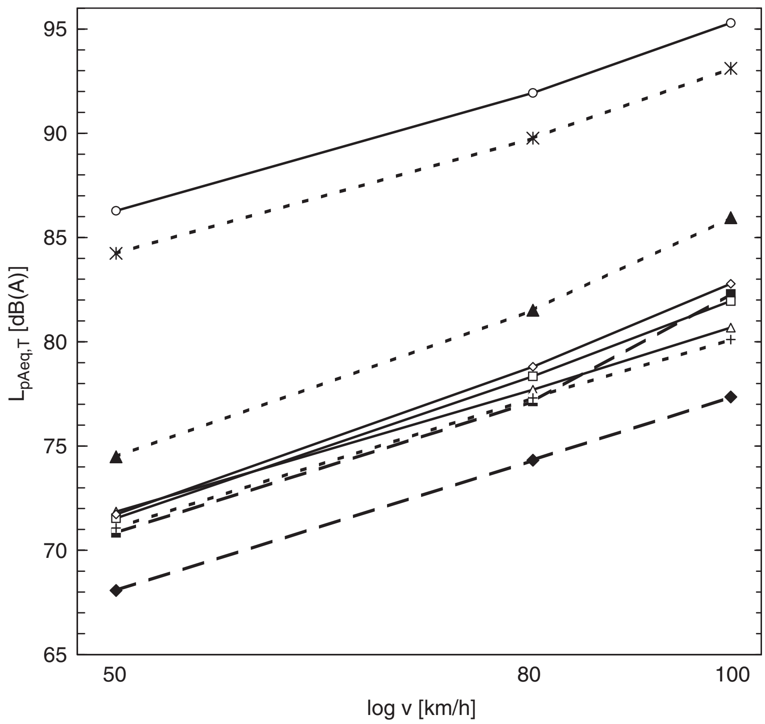

Fig. 4. The equivalent sound pressure level of the different types of freight wagons at different velocities. –◆– Habbinss-14 (Y25), –■– Habbinss-14 (DB 656), –▲– Sgnss (UIC wheel), - + - Tagppns, —□— Sgnss (0 km), —◇— Sgnss (1000 km), - ▲ - Hbbillnss, - ✱ - Fans-u, —○— Sgnss (cast iron).

relative to the noise of cast iron block braked vehicles can be observed (comparable with results in Refs. [7,8]). As long as only pass-by noise is dominant, the speed dependency follows exactly the 30 log V characteristics (where V is the train speed). Some vehicles show a higher rate between 80 and 100 km/h than below 80 km/h. The main reason for this effect was that some vehicles started to run unstably at 100 km/h (especially the Habbinss-14 with DB 656 bogies and the Hbbillnss two axle wagons).

The general noise level of the Fans-u wagons is much higher than expected, nearly at the level of the Sgnss wagon with cast iron brake blocks. The wheel roughness of these two wagon types is at a similar level, too. The Fans-u wagons are mainly used for transport of excavation material from the new alpine tunnels in Switzerland into gravel works. In fact, because of the short length of wagon, a higher level compared to the other four axle wagons was expected, but this cannot fully explain this range. The assumption therefore is, that sand and stones on the rail surfaces at the tunnel workshops and gravel works damage the wheel surfaces of these wagons.

For the two axle Hbbillnss wagon, a lower noise level than for the Habbinss-14 four axle wagon was expected due to the reduced number of axles per wagon length. But all of the Hbbillnss wagons had small wheel flats, which were not observed before and therefore showed a noise behaviour worse than expected.

The Habbinss-14 was originally rented with DB 656 bogies. Three wagons were operated with those original bogies and wheel sets with an unknown running distance since the last reprofiling. On the other three wagons the bogie was exchanged to Y25 type without changing anything at the braking system. Those three wagons received newly reprofiled wheelsets, which ran 1000 km before the measurements. But the roughness difference is small and does not explain the pass-by noise difference. The DB 656 bogie allows some radial steering of the wheelsets. These movements of the axle boxes relative to the bogie frames lead to a squealing-like noise, which is the relevant cause for the noise level difference.

In Fig. 5, all noise levels measured at the site in Kerzers at 80 km/h are presented. Energetic mean value, standard deviation (grey block) and total range are presented.

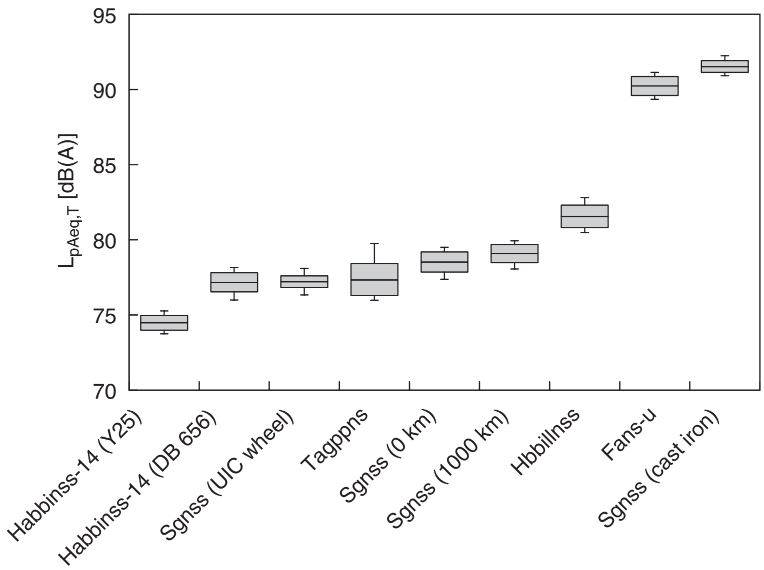

Fig. 5. Energetic mean value, mean value plus and minus standard deviation (block), minimum and maximum of the sound pressure level as measured in Kerzers at a velocity of 80 km/h.

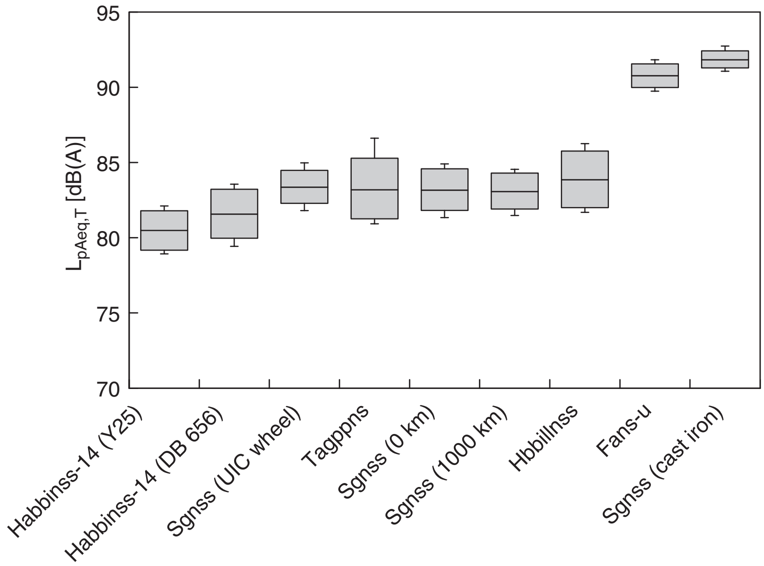

Fig. 6. Energetic mean value, mean value plus and minus standard deviation (block), minimum and maximum of the sound pressure level at a velocity of 80 km/h, calculated for the rail roughness as defined in prEN ISO 3095 [2].

Based on the measured rail roughness data, it was possible to calculate the noise level, which the respective vehicle would have produced on identical track but with a rail roughness according to the limit curve of prEN ISO 3095 [2]. In Fig. 6, it can be observed that the levels of the noisy vehicles are not influenced, because the wheel roughness dominates the total roughness. The noise levels of quiet vehicles are increased and the differences become smaller because the rail roughness dominates the total roughness.

In Fig. 7, it can be observed, that even with the limit curve of the TSI HS [3], the noise level of quiet vehicles increases. Fig. 2 shows, that the rail roughness in Kerzers is lower than the TSI HS [3] requirement for

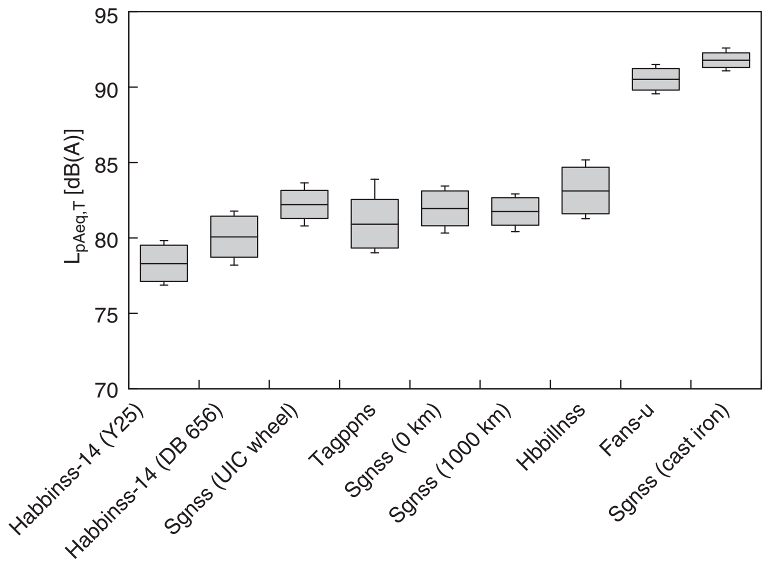

Fig. 7. Energetic mean value, mean value plus and minus standard deviation (block), minimum and maximum of the sound pressure level at a velocity of 80 km/h, calculated for the rail roughness as defined in the technical specification for interoperability for the trans-European high-speed rail system.

wavelengths shorter than 8 cm. Currently, freight trains are mainly operated at speeds below 120 km/h where the long wavelengths do not have a significant influence on pass-by noise.

It could be observed that braking the train before the measurements did not influence the pass-by noise level of composite block braked vehicles. The noise level on the cast iron block braked wagon group was increased by an amount smaller than the measurement accuracy.

It is obvious that there is a considerable reduction between cast iron block braked vehicles and composite block braked vehicles in good conditions. Therefore, it was feasible to propose one limit value without taking into account additional parameters like number of axles per metre to meet the goals presented in Section 1.

Concerning the pass-by noise a difference between the standard UIC wheel type Db 10 and the low stress wheel type Db 11 Sa could not be identified.

It could be observed, that with a reasonable accuracy the pass-by noise of a vehicle can be determined by total roughness (wheel and rail), number of axles per metre and speed of the wagon. Therefore, wagon superstructure, wheel type, bogie type, type of reprofiling and running distance do not play a relevant role.

3.2. *Definition of test procedures*

In combination with the proposal for the limits, a test procedure had to be proposed, which can be applied to check whether a vehicle meets the limits or not.

It is proposed to brake the wagons prior to the measurements. Following the braking, the pass-by noise of cast iron block braked vehicles will stay at their high noise level. If the wheels have been reprofiled recently and the brakes not used before, it is known that only one intensive brake application is sufficient to move the cast iron braked wheel roughness to their typical high level [9]. This allows, that requirements on the history of the wagons, especially the wheel surfaces become obsolete.

The rail roughness shall not be higher than the wheel roughness of composite block braked wagons in a good status because wagons shall be judged by the measurement. Therefore, the roughness requirement of prEN ISO 3095 [2] is not sufficient. It is proposed to use the requirement of TSI HS [3]. When TSI CR [4] becomes definitive it can be applied instead of TSI HS [3].

Studies were also executed on the influence of a noisier wagon to an adjacent wagon group and compared with the results of Ref. [10]. The real differences in the test train were measured and the influence to an adjacent wagon group with different parameter sets (number of wagons in a wagon group, difference of noise level between two wagon groups) was checked. The goal was to define a minimum number of wagons to achieve a measurement with a reasonable accuracy. With three wagons per group and measuring the $L_{pAeq,T}$ from the middle of the first wagon to the middle of the third wagon, if the adjacent wagons are 5 dB(A) noisier, the resulting $L_{pAeq,T}$ is 0.53 dB(A) too high. If the adjacent wagons are 10 dB(A) noisier, the resulting $L_{pAeq,T}$ is 1.87 dB(A) too high. It is interesting, that the bonus, which applies to the wagon group at the end of the train (with no adjacent wagon on one side) is less than 0.27 dB(A) and can therefore be neglected. It is expected, that the suppliers and operators will just subject wagons to measurements, which have a chance to fulfil the tests. Therefore, the difference of noise level will typically be smaller than 10 dB(A).

3.3. Proposed limit value and test conditions

As limit value for retrofitted freight wagons it was proposed:

$$\mathrm{TEL}(v(\mathrm{km/h}))(\mathrm{dB(A)}) = L_{pAeq,T}(v(\mathrm{km/h}))(\mathrm{dB(A)}) \leqslant 85\,\mathrm{dB(A)} + 30\,\log\left(\frac{v(\mathrm{km/h})}{80\,\mathrm{km/h}}\right). \quad (1)$$

As conditions, it was proposed to apply the conditions of prEN ISO 3095 [2] with the following exceptions:

The history of the wagons is not important (the original requirement, that 1000 km should have been run before the measurements can be omitted). Wagons are allowed to be tested with any wheel condition; even new wheels and recently reprofiled wheels are allowed as long as at least one brake operation has been carried out.

For the noise measurements, a test train shall be composed with three wagons of each wagon type to be tested. The measuring time T for the $L_{pAeq,T}$ starts in the middle of the first vehicle of a group and ends in the middle of the third vehicle of the same group.

The test train shall be braked down from maximum speed of the wagons to a complete stop by a full brake (pressure in the brake pipe reduced to 3.3 bar [11]) immediately prior to the noise measurements. This is done twice. Each wagon has to brake its own weight completely. Therefore, the maximum speed of all wagons tested together shall be identical.

The speed for the measurements is 80 km/h and the maximum speed of the wagons. It is allowed to measure in both directions.

The rail roughness at the measuring location has to be known and has to fulfil the requirements of TSI HS [3].

If the $L_{pAF,\max}$ of a wagon group is more than 10 dB(A) higher than the $L_{pAF,\max}$ of an adjacent group, the noisier wagon group has to be taken out from the test train. No analysis of the $L_{pAeq,T}$ is required for this decision, an estimation on the basis of the $L_{pAF,\max}$ is sufficient. The tests have to be carried out from the beginning with the reduced test train.

In fact this limit only had to be proposed for retrofitted wagons. From a technical point of view it has to be stated clearly, that the behaviour of new wagons with the same technology (bogies, wheels and braking systems) as they are built today in large numbers is identical and will produce exactly the same noise levels and therefore should not be handled separately.

3.4. Effects diminishing the noise reduction

It was observed during the measurement campaign, that the noise reduction, which is achieved by composite brake blocks, could be affected by several effects.

The objective of the noise reducing measures (such as replacing cast iron brake blocks by composite brake blocks) is not only to pass a type test but primarily to achieve a sustained noise reduction during the lifetime of the vehicle in normal service. Therefore, measures to eliminate or reduce the effects producing additional noise had to be proposed.

As discussed earlier, the noise production is dominated by the rail on a track with high rail roughness (see the three bars on the left-hand side in Fig. 8). The change from cast iron brake blocks to composite brake blocks yields a noise reduction of 12–14 dB(A) on a track in good condition as at the measuring site in Kerzers. On a track with a roughness as per prEN ISO 3095 [2], this noise reduction of 12–14 dB(A) is diminished by

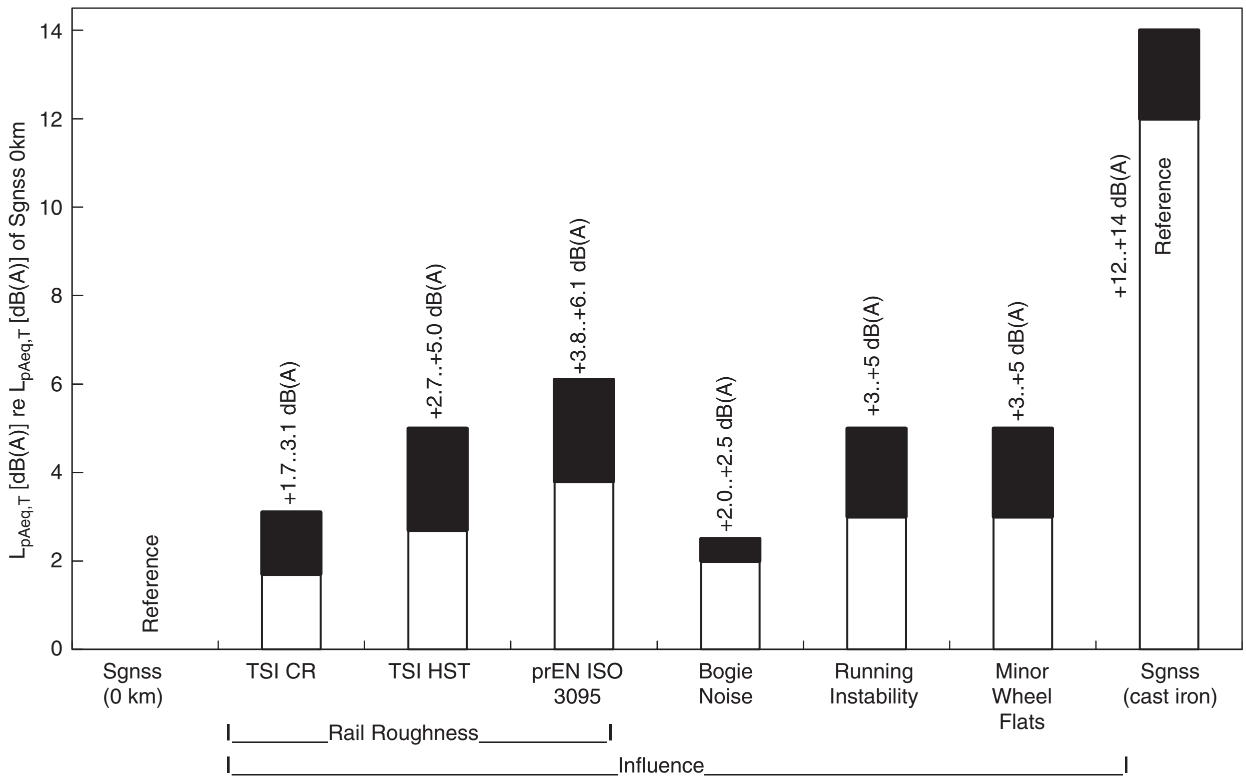

Fig. 8. Loss of noise reduction due to different effects.

3.8–6.1 dB(A) only due to the higher rail roughness. That means, that up to 50% of the noise reduction, which was achieved by the use of composite brake blocks, can be lost.

The noise of insufficiently greased DB 656 bogies can decrease the noise reduction by 2.0–2.5 dB(A). Wheel flats can compensate for the noise reduction completely. Vehicles with no visible wheel flats prior to the test were chosen for the test train; it is however possible, that invisible wheel flats were present. Just the noise of such invisible wheel flats diminishes the noise reduction by 3–5 dB(A). Moreover, a 3–5 dB(A) diminishing of achievable noise reduction was recorded as a consequence of unstable running, and even higher values are possible.

4. Measures to ensure the noise reduction

Measures are required to eliminate the effects presented in Section 3.4 and to ensure a sustained noise reduction for the full lifetime of a freight wagon:

By measuring the track parameters, the roughness of the running surface as well as the equivalent conicity with a wheel profile S1002 [12] has to be recorded (methods have to be made more efficient for a routine usage of them). The running surface of the rail has to be ground on sections with a rail roughness higher than TSI HS [3] or with an equivalent conicity higher than 0.3. This ensures a low roughness together with a high probability of stable running.

An improvement of the freight wagon brake systems cannot be realised in the near future. Therefore, the measures to minimise wheel flats, which can be realised soon, are very limited. As most freight wagons are not equipped with a wheel slide protection system, the adjustment and maintenance of the brake system has to be established with a higher accuracy and shorter maintenance intervals or diagnosis and short reaction times. This requires mainly periodic greasing of the system and checking that the brake force is correct and evenly distributed. Wheel flats have to be monitored (line side monitoring stations are proposed), vehicles should be equipped with tags in order to be identified and wheels with flats shall be reprofiled or ground.

In parallel to such checks and greasing of the brake system, movable bogie parts like the axle guiding of DB 656 bogies have to be greased as well to avoid squealing noise while running. The whole wagon shall be checked for rattling components. During the measurements, rattling was observed just for the case of unstable running but as it will also occur on switches and with changes in the longitudinal force, it has to be eliminated to gain the whole noise reduction of composite block brake systems.

5. Conclusions and recommendations

The exchange of cast iron brake blocks by composite brake blocks is a low-cost measure, which allows a noise reduction of up to 12–14 dB. To ensure a sustaining noise reduction, the track has to be maintained with a roughness not higher than the wheel roughness and an equivalent conicity ensuring stable running. The vehicle has to be well maintained to avoid wheel flats and squealing or rattling parts.

Compared with the installation of a local measure like noise barriers, the benefit of this measure is more efficient because it reduces noise everywhere where the wagon is operated.

Acknowledgements

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