EXPERIMENTAL STUDY AND ANALYSIS OF A NEW WHEEL/RAIL CONTACT NOISE ABSORBER

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Abstract: *In this work an experimental study of a new construction for reduction of the noise emitted by the wheel/rail contact during railway vehicles motion is done. Noise pressure levels measurement in different settings of the absorber is made. On the base of the analysis of the results, conclusions for its practical implementation are stated.*

Key Words: *Noise, railway noise absorber, noise pressure level.*

1 Introduction

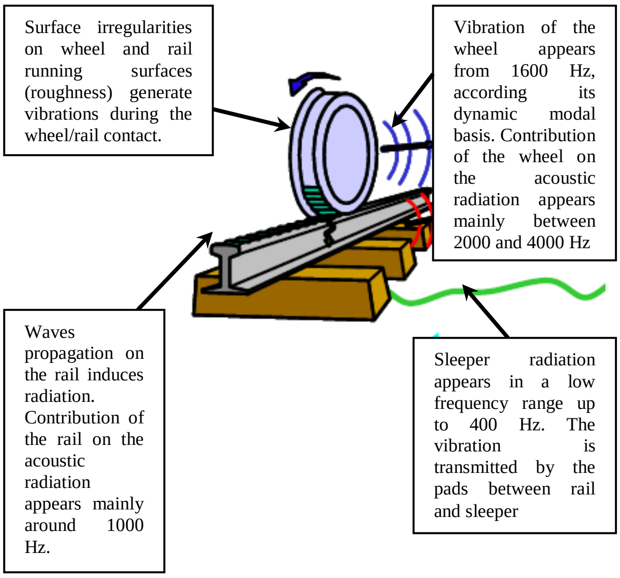
The railway transport is the only alternative to the fast industry and population growth with its unlimited opportunites for development. New railway projects around the world plus upgrading/expanding existing railway lines caused orders in virtually all market segments to surge. According to studies, the total annual world market for the rail supply industry in 2007 is estimated at more than €120 billion, out of which €85 billion is accessible. As for the annual growth rate, it is considered to be between 2,0% and 2,5% over the next nine years [Hardey AEJ and Jones RRK., 2004].

Railway operational noise originates from a number of sources. These include the engines and cooling fans of locomotives, the under-floor engines of "diesel multiple units" (self-propelled sets of railway coaches), gears, aerodynamic effects at higher speeds, and the interaction of wheels and rails. The latter source tends to have an influence on overall noise levels at speeds above 50 km/h and is normally predominant at speeds above around 100 km/h [Hardey AEJ and Jones RRK., 2004].

It is stated that up to 50 km/h, railway noise is dominated by traction noise which consists of motor noise and auxiliary noise, from 50 km/h up to 300 km/h, noise emission is dominated by rolling noise and Above 300 km/h, aerodynamic noise becomes predominant. These transition speeds are not strictly fixed and depend on many parameters, for example rail and wheel maintenance conditions for the rolling noise. Other sources can be identified in specific operating conditions like during bridges passing, curves passing, rail joint passing, breaking etc. [Hardey AEJ and Jones RRK., 2004].

Wheel/rail noise, or "rolling noise", results from the vibration–excitation of the wheels and track as the wheel rolls on the rail. The excitation is provided by the combined surface roughness at the interface, or "contact patch", between the wheel and the rail. Because the entire wheel and track system is excited by the combined roughness at the interface, it is this combined value that determines the level of rolling noise rather than the individual rail and wheel roughness components. Rolling noise is mainly excited by rail and wheel roughness in the wavelength range from 5-500 mm [Thompson D. J. and Jones C. J. C ,2000; Hubner Peter, 2005].

It is now well established that rolling noise is caused by structural vibrations of the wheel, rail and sleepers induced by the combined roughness of the wheel and rail running surfaces as illustrates Figure 1.



Surface irregularities on wheel and rail running surfaces (roughness) generate vibrations during the wheel/rail contact.

Vibration of the wheel appears from 1600 Hz, according its dynamic modal basis. Contribution of the wheel on the acoustic radiation appears mainly between 2000 and 4000 Hz

Waves propagation on the rail induces radiation. Contribution of the rail on the acoustic radiation appears mainly around 1000 Hz.

Sleeper radiation appears in a low frequency range up to 400 Hz. The vibration is transmitted by the pads between rail and sleeper

Figure 1: Illustration of the physical mechanism of the rolling noise [Hubner Peter, 2005].

Parameters influencing the rolling noise generation:

- Roughness
- Type of braking system and wheel maintenance (subsidiarily)
- Rail maintenance
- Contact patch
- Wheel load
- Wheel and rail profiles
- Number of wheels
- Wheels and rails defects (wheel flats)
- "Parametric excitation"
- Train speed
- Sleeper spacing
- Statistical variation of mechanical characteristics of track components

Many years of research and engineering have led to package of solutions for noise reduction. Some of them are summarized in the table 1, and particular realisations are shown on figure 2 [Trevor J. Cox and Peter D'Antonio, 2009; Oertly Jakob and Hubner Peter, 2010; Jansen Erwin, 2008; D. Benton et al., 2008].

A new method for active noise absorbtion of the noise generated by the wheel rail contact of rail-bounded transport (figure 3-a) has proposed by the authors [Kralov, Terzieva, Ignatov, 2011]. The idea of suggested method is to capture and absorb the radiated sound in small volumes near the track. The essence is to install fixed, noise absorbing tube-like constructions parallel to the track trajectory. They are situated according figure 3-b near the track and find its application in railroad construction, in railway stations, rail tunnels (figure 3–c).

2 Aim of the study

Table 1. Methods for noise reduction

	Noise reduction method	Overall reduction potential	Noise reduction effect	Comment/status
1	Retrofitting with K-blocks	8-10 dB	Network wide	K-blocks are homologated however require adaptation of the braking system
2	Retrofitting with LL-brake blocks	8-10 dB	Network wide	LL-brake blocks are only provisionally homologated
3	Wheel absorber	1-3 dB	Networks wide	Effect strongly depend on local conditions. Wheel maintenance difficulties may occur
4	Track absorbers	1-3 dB	Local	Track maintenance difficulties may occur, effect strongly depends on local conditions, not homologated in many countries
5	Acoustic rail grinding	1-3 dB	Local	Effect strongly depends on local rail roughness conditions, smooth wheels are precondition for effect
6	Operational	Variable	Local	Negative effect on the operations and railway capacity. The method hinders railway traffic therefore not in line with efforts to promote sustainable transport
7	Noise barriers	5-15 dB	Local	Effect depends on height and local geography, negative effect on the landscape, influence on railway maintenance procedures
8	Noise insulated windows	10-30 dB	Local	Effect is only achieved only when windows are closed

The goal of this work is to investigate experimentally the parameters influence on the degree of absorption of a proposed construction under the new method. Ray-tracing calculations can only be carried out for objects further than 1,5 meter from the track. This could be an argument to include all effects at shorter distances in the source description. For small barriers near the track, a correction dependent on distance and height could be added to the source module. Possibly this factor could be dependent on barrier material, train type, etc. [U. Moehler et al., 2008; R. R. K. Jones et al., 2007; Draft JRC Reference Report, 2010; Burkhard Schulte-Werning et al., 2007; O.B. Godbold, R.C. Soar and R.A. Buswell, 2007; Ulrik Danneskiold-Samsøe et al., 2002].

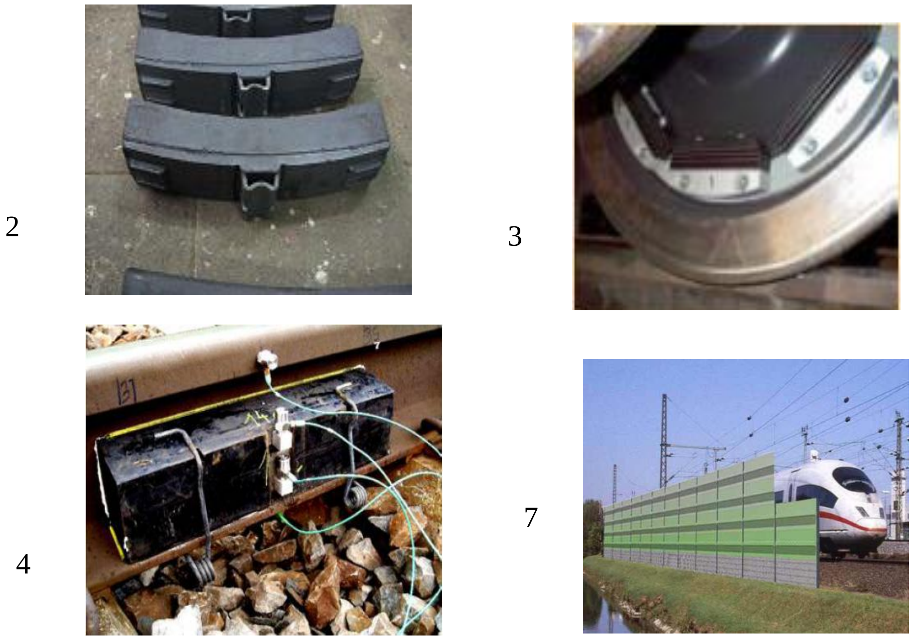


Figure 2: Some examples of noise abatement according to table 1

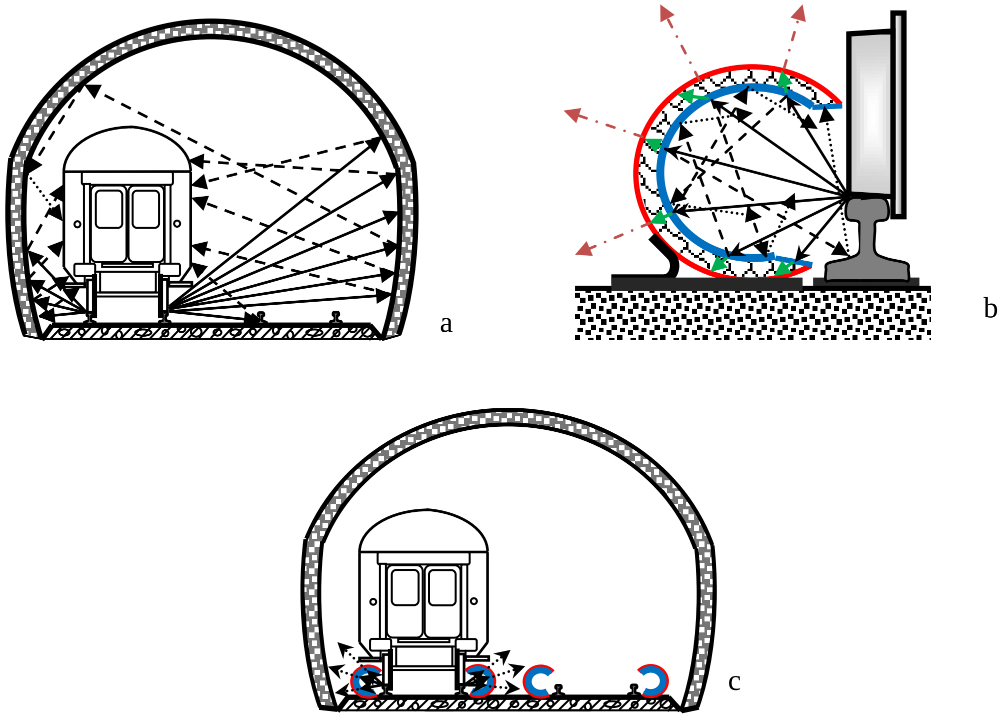


Figure 3: Application of the noise abatement construction

3 Experimental setup and procedure

The experimental setup for this study is presented on figure 4. It is allowed the study of absorbing constructions in small chambers (50x55x100 cm). The chamber used has inside flat walls for better noise diffraction, and outside is covered with sound absorbing materials. For the testing is used “white” noise generator, having frequency span of “white” noise generation from 500 Hz up to 8 kHz. The measurements are realized with noise measuring system Brul&Kjaer PULSE. As a receiver it is used microphone type 4958 from array series, having nominal sensitivity of 12,5 mV/Pa. Its position was out of influence of any vibrations cause by the source. A number of parallel filtering operations are made to analyze the frequency range selected. The constant percentage bandwith measurements were done with the following properties: bandwith 1/3 octave; exponential average mode; exponential averaging time ¼ s with free run triggering; lower center frequency - 16 Hz; upper center frequency - 10 kHz. The result testing is repeated also with A weighting. All the results are collected according to the standards and legislations concerning calibration and testing procedures, as well as measurement error evaluation.

Two probes are tested as the results are shown on figure 5. The first one is PVC tube having no treatment in the inside planes, and it has 60^{o} opening cut through the radius of the tube. The second probe has installed mineral wool, along the PVC tube inner surface. The results from the testing are discussed in section 4.

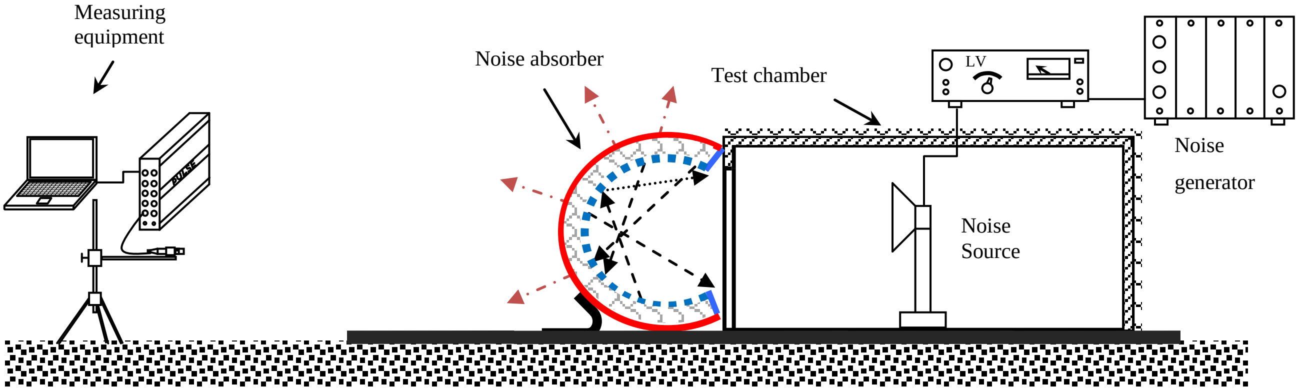


Figure 4: Noise absorber testing procedure

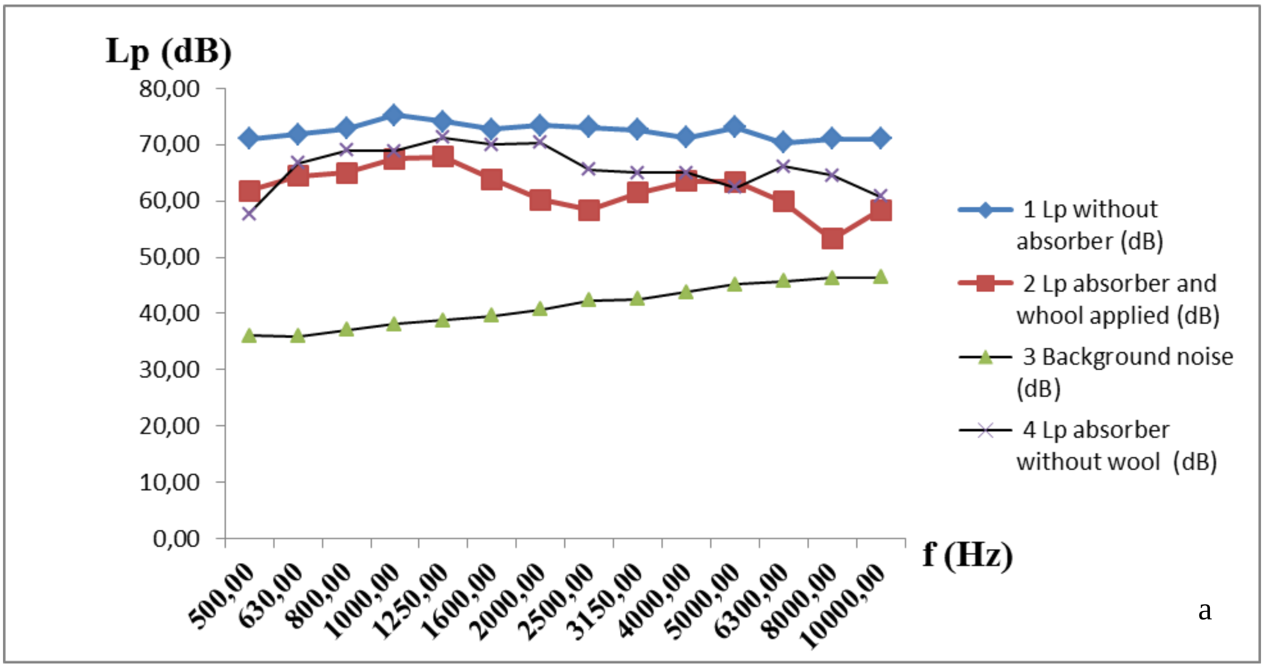


Figure 5-a: Results obtained with the noise absorber

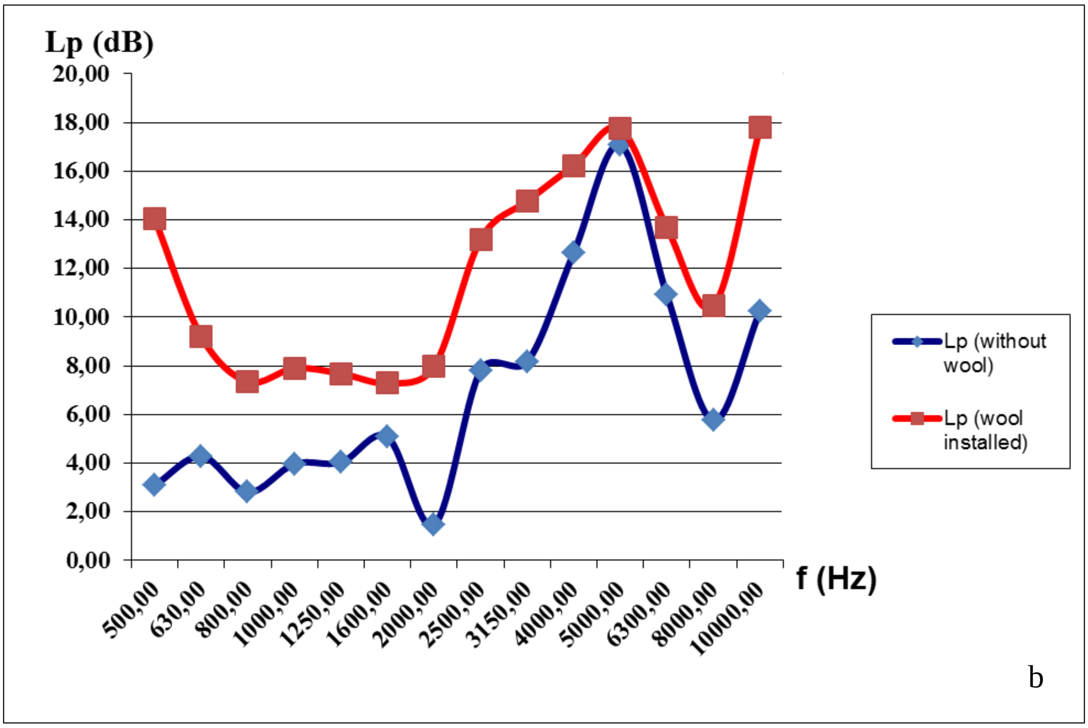


Figure 5-b: Results obtained with the noise absorber

4 Results analysis and discussion

According to the testing procedure shown on fig. 4 and described above, a number of experiments were made. The noise levels in a 1/3 octave discrete frequency spectre from 500 Hz to 10000 Hz, are presented on figure 5.

On graphic 5-a the line (1) presents the noise level Lp (dB) measured according the testing procedure, without absorber. The “white” noise level is “deformed” with variation of the level up to 10 dB and the peak levels are reached in the range of 3150-5000 Hz, as the highest point is at 4000 Hz – respectively 81,2 dB. This is due to the strong influence of the rolling noise in this frequency range.

The line (2) presents noise levels Lp (dB) with applied absorber having mineral wool on the inner surface of the device. The results show a significant reduction of the noise levels: the average reduction realized in the whole tested frequency range is 11,12 dB; the noise level is reduced significantly in the range from 1250 to 4000 Hz up to 16,24 dB. The highest reduction of 17,75 dB is reached at 5000 Hz.

The line number 3 presents the measurement results with applied absorber having no mineral wool applied on the inner. The average reduction is 7,71 dB in the whole measured frequency range. The peak level of 17,07 dB reduction is reached at 5000 Hz. This is close to the results, realized with the mineral wool applied.

The line number 4 shows the level of background noise. The result show more than 10 dB difference between all other results in the investigated range, which proves the correctness of the measurement.

All the data collected is published after number of tests realized according to the RMS (Root Mean Square) function of the measuring equipment and software.

Figure 5-b represents the reduction of the noise levels in case the device has installed mineral wool along the inner surface of the device (the upper line) and without wool (the lower line).

These results show that the application of the PVC tube construction without wool inside, the reduction of the noise level is about 4 dB in the frequency range 500-1600 Hz and more than 10 dB in the range 3150-6300 Hz.

The construction of the absorber with mineral wool inside gives reduction of the noise levels more than 7 dB in the frequency range 500-2000 Hz and more than 14 dB in the range 3150-6300 Hz.

In both constructions the noise level reduction at 5 kHz 1/3 octave is about 17 dB.

If we switch the logarithmic scale to exponential one, according to the formula

$$L_P = 20\log\frac{P}{P_0},$$

where $P_0 = 20\ \mu Pa$, we shall determine the sound pressure in Pa. It is well known that 6 dB equals to double change of the sound pressure. For example at frequency 5000 Hz the pressure is 0,229

Pa without the absorber, while with the absorber having mineral wool applied, the pressure is 0,0297 Pa. This is more than 7,7 times reduction of the sound pressure.

5 Conclusions

An experimental study of a new construction of a rolling noise absorber is presented in this paper. Noise pressure levels measurement in different settings of the absorber is made.

Both constructions give the noise level reduction more than 10 dB at frequency range 3150 - 6300 Hz. This is very promising result, taking into account that according [A. Van Beek et al. 2002] the acoustic radiation of the rolling noise occurs mainly between 2000 and 4000 Hz. In the investigated range the total reduction is averaged 11,12 dB with the construction having mineral wool installed, and 7,71 dB averaged without the wool installed.

In this particular constructions the materials used are having low cost, and have certain durability.

The next investigations have to answer the questions for parameter optimization of the absorber, adding of new filters to improve the coefficient of absorption in some specific frequency ranges etc.

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ЕКСПЕРИМЕНТАЛНО ИЗСЛЕДВАНЕ И АНАЛИЗ НА НОВ ЗАГЛУШИТЕЛ НА ШУМА ОТ КОНТАКТА КОЛЕЛО-РЕЛСА

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Резюме: *В настоящата работа е извършено експериментално изследване на нова конструкция за снижаване на шума от контакта колело-релса, породен при движението на железопътни превозни средства. Направено е замерване на нивата на излъчваният шум при различни конструктивни решения на заглушителя. Въз основа на анализа на резултатите са направени изводи за практическото реализиране на устройството*

Ключови думи*: Шум, заглушител на ж.п. шум, ниво на звуково налягане.*