Influence of Sleeper Type on Train Emission

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Summary

In the course of this work the emitted sound power spectra of different train types on a ballasted track were measured and evaluated. The measurements were carried out on a track were the sleeper type changes from a wooden type to concrete type. The evaluations are carried out by means of the A-weighted linear sound power level and by means of the psychoacoustic measure of the acoustic sharpness. The evaluation focuses on the difference between the noise emissions on wooden and on concrete sleepers. This analysis is of great importance for the planning of new railway infrastructure for predicting the correct train noise emissions in order to comply with the immission limits of the neighboring environment.

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1. Introduction

The sound emission of railed vehicles is a physically complex effect of great importance for the planning of new railway infrastructure. Therein, the emitted noise needs to be predicted in order to comply with sound immission limits. In the rail-bound traffic the primary source of noise and vibration is the wheel-rail system. Based on the different properties of vehicle and superstructure the emission of direct and secondary airborne noise from the area of bogie and ballasted superstructure results from different mechanisms. Among others there are vibration excitation of wheel and rail, vibration propagation in the rail, vibration transmission into the bogie and the carriage, sound emission of the vibrating parts and sound propagation under the carriage.

In the framework of urban railway traffic the sleeper type is of great interest. Concerning this matter, there is the common believe that the sound emissions are higher if concrete sleepers are used instead of wooden sleepers on a ballasted track. However, this interrelation so far could not be proven by existing measurements.

As the choice of sleeper type influences on the emissions to be expected, this topic is crucial for the design of new railway tracks or railway tracks that are to be renovated. In order to clarify the point of noise emission of wooden and concrete sleepers, respective measurements were carried out on behalf of Austrians Federal Railways (ÖBB). Within an extensive project, focusing on the radiated sound power spectra of urban light rail vehicles in Vienna, the emissions on wooden and on concrete sleepers in a ballasted track bed were measured and compared. The comparison is carried out in terms of the linear sound power spectrum and the psychoacoustic measure of sharpness. A detailed documentation of the whole measurement campaign is given in [1].

2. Measurement

The evaluation of the linear sound power level L_W according to the ÖNORM S 5026 [2] is based on the pass-by measurement of the emitted airborne noise at three positions on a 15 m radius around the track.

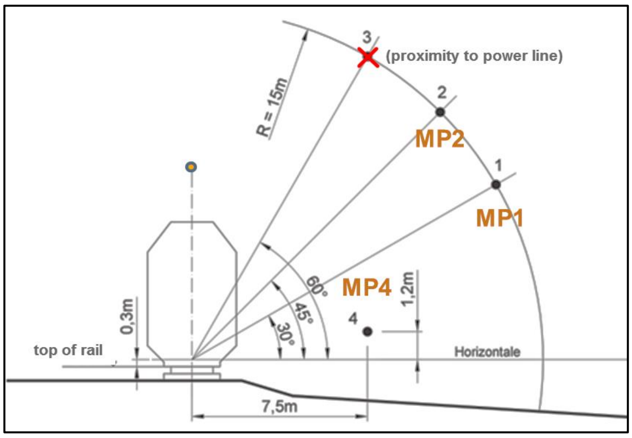

Figure 1. Positions for the measurement and evaluation of the linear sound power level according to the ÖNORM S 5026 [1].

Figure 1 shows the positions for the measurement of the airborne noise level according to this normative. The pass-by sound power level is obtained by averaging the results of measurement points MP1, MP2 and MP3. In this project the MP3 was omitted due to its crucially low distance to the power cable for security reasons.
The measurement for the determination of the difference in sound emission between wooden and concrete sleepers was carried out on a straight track featuring a change of sleeper type from wood to concrete, see Figure 2.

Figure 2. Test track for the estimation of the difference in emitted airborne sound depending on the sleeper type.

In the measurement setup one cross section of the track was instrumented for each sleeper type. This optimal configuration enables the evaluation of the emission differences with high comparability. In this setup the comparison is carried out by passings of the same vehicles at almost the same velocity at comparable surroundings and equal atmospheric conditions featuring the same ballasted superstructure. Consequently, all noise variations measured between the two cross-sections can be related to the sleeper type.

3. Evaluation

The analysis is done in terms of two parameters. Firstly, the linear acoustic sound power is used to compare the emissions of the different categories.

The evaluation of the linear sound power level was carried out according to the ÖNORM S 5026. The sound power emission of a certain vehicle type $L_{W,i}$ on a certain sleeper type is obtained by averaging at least three pass-by measurements:

$$L_{W,i} = 10\,\lg\left[\frac{1}{3}\sum_{i=1}^{3} 10^{\frac{L_{W,i,j}}{10}}\right], \qquad (1)$$

where $L_{W,i,j}$ is the sound power of i-th pass-by of the j-th frequency band. The A-weighted linear sound power level is evaluated by

$$L_{W',A} = 10lg\sum_{i=1}^{8} 10^{(L_{W',j}+A_i)/10}, \qquad (2)$$

where A_i are the weighting factors of the octave bands.

Secondly, the psychoacoustic value of the “sharpness” is used in order to evaluate the subjective perception of the different noise spectra. The acoustic sharpness with the unit acum is a quantity defined in psychoacoustics, [3]. It quantifies the perceived sharpness of a signal based on special weighting curves for the psychoacoustic Bark-bands. A signal is perceived to be sharp if in the presence of dominant high frequencies there is a lack of low frequencies in order to balance the whole spectrum to give a pleasant sound.

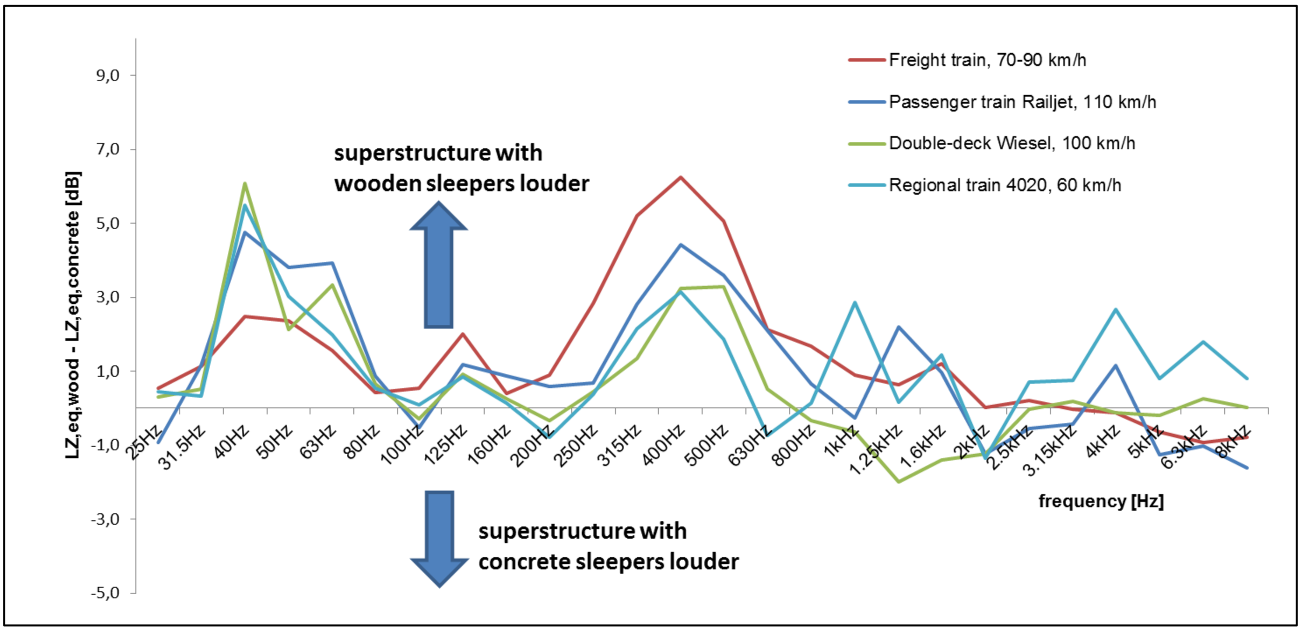

Figure 3. Difference of the emissions on wooden sleepers compared to the emissions on concrete sleepers.

4. Results

In the following only the differences between the emissions on wooden and concrete sleepers are analyzed. The absolute values can be found in [1].
In Figure 3 the differences between the emissions on wooden and on concrete sleepers are analyzed for different train types in terms of the averaged pass-by sound pressure level. Looking at the third-octave band spectra reveals similar qualitative and quantitative results for all train types. The greatest difference between wood and concrete lies in the frequency range between 250 Hz and 600 Hz. At a frequency of 400 Hz the emissions of freight trains on wooden sleepers is 6 dB above the emissions of concrete sleepers, respectively. Furthermore, the emissions on wooden sleepers show a significant excess of 4 dB - 5 dB in the frequency area between 31,5 Hz and 80 Hz.
In addition to the above described measurement cross-section, further measurements have been carried out on a further track in Vienna on a curved track where the inner track features

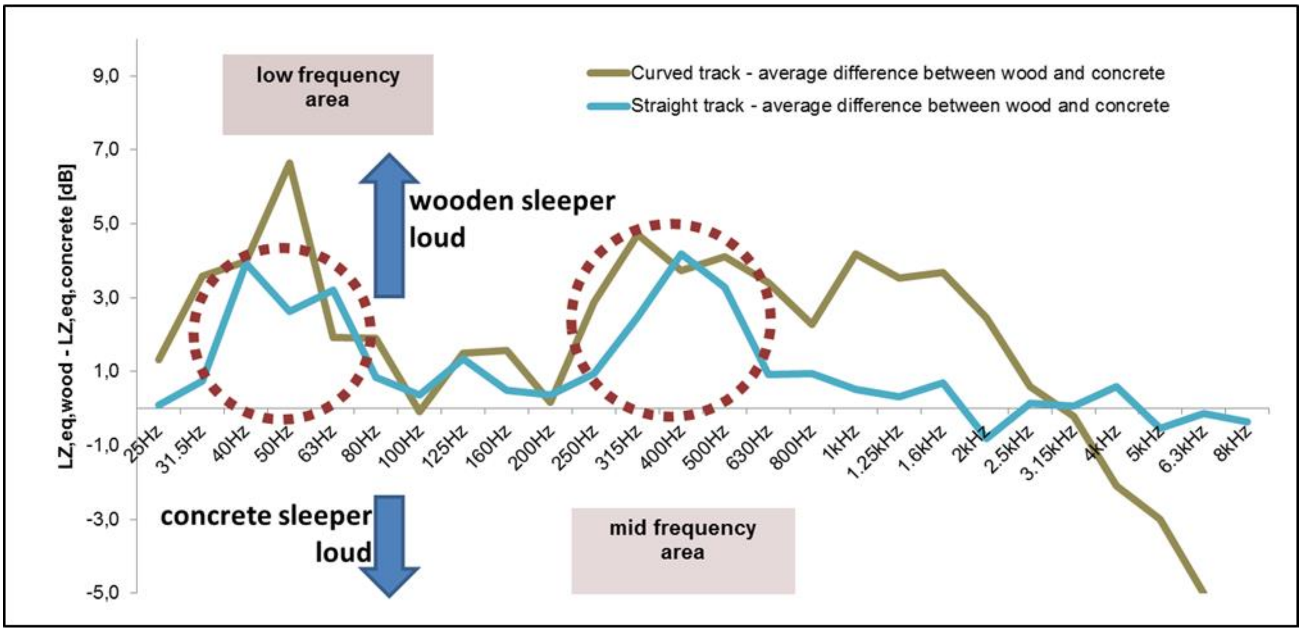

Figure 4. Difference of the emissions between wooden and concrete sleepers for the straight and the curved track averaged over all train types.

Table I. Comparison of the emissions between wooden and concrete sleepers.

			difference between wooden and concrete sleepers	
track	*type*	*speed*	*LWA' [dB(A)]*	*Schärfe [Acum]*
curved	Talent	70 km/h	3,1	-0,11
	Talent	60 km/h	2,6	-0,30
	Stadler	60 km/h	2,4	-0,54
curved	**averaged**		**2,7**	**-0,32**
straight	Railjet	110 km/h	1,6	-0,06
	Güterzug	80 km/h	2,1	-0,06
	Doppelstock	100 km/h	0,6	0,02
	Doppelstock	70 km/h	1,6	-0,03
	4020	60 km/h	0,8	0,03
straight	**averaged**		**1,3**	**-0,03**

wooden sleepers and the outer track features concrete sleepers. Several train types have been measured in this configuration.
Figure 4 shows the final summary of the spectral differences between wooden and concrete sleepers on the straight and the curved track. Therein, the results of all train types were averaged. In both track types the frequency area between 31,5 Hz and 63 Hz is significant where the emissions on wooden sleepers are 3-5 dB higher than the emissions on concrete sleepers. The second significant area reaches from 250 Hz to 600 Hz on the straight track and from 250 Hz to 2,5 kHz on the curved track.

In order to achieve a single valued objective comparison between the two sleeper types two measures are now given for each category: the A-weighted linear sound power level and the acoustic sharpness.
Table I shows the summarizing comparison of linear sound power level and acoustic sharpness for different train types on the straight and on the curved track. Again, only the difference between the values for concrete and wooden sleepers is shown.
It results that the A-weighted emissions on wooden sleepers are between 0,6 dB(A) and 3,1 dB(A) higher than on concrete sleepers. The increase averaged over all train types yields 2,7 dB(A) on the curved track and 1,3 dB(A) on the straight track.
On the other hand, the acoustic sharpness is higher on concrete sleepers than on wooden sleepers by trend. This effect can strongly be observed on the curved track whereas it is minor on the straight track.

5. Interpretation

The higher sharpness on concrete sleepers can be explained by the interrelation that the emissions in the low frequency spectrum are less than on wooden sleepers whereas the high frequency emissions contain the same power on both sleeper types. The higher relative weighting of the high frequencies is perceived as increased sharpness.
Several reasons can be found for the spectral differences that are based on mechanic, geometric and acoustic properties of both sleeper types. The severe study of the respective interrelation needs in-depth investigation. Nevertheless, fundamental mechanisms shall quickly be named.

1.1. Acoustic properties

Table II compares the acoustic absorption coefficients of concrete, wood and ballast. Wood shows low absorption, whereas concrete acts as a good reflector. On the other hand, the ballast bed features strong acoustic absorption.

Table II. Coefficients of acoustic absorption of concrete, wood and ballast bed [4,5,6].

	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Concrete	0,01	0,01	0,02	0,02	0,02	0,02
Wood	0,15	0,11	0,10	0,07	0,06	0,07
Ballast bed	0,17	0,34	0,25	0,50	0,62	0,63

1.2. Mechanic properties

Both sleeper types feature a dominant fundamental bending resonance in the area between 500 Hz and 800 Hz. In this area the emissions of wooden sleepers are higher than the emissions of concrete sleepers.

1.3. Geometric properties

The wooden sleepers feature a rectangular cross-section with a height of 16 cm and a width of 26 cm. In contrast the concrete sleepers are significantly thinner especially on the upper surface. This relation has two effects:
(A) Firstly, the use of concrete sleepers on a ballasted track increases the surface area of highly absorbing ballast, in comparison to the use of wooden sleepers. Consequently, the sound emitted by the wheel rail system is absorbed to a greater extent.
The second effect (B) considers the vibrating sleeper that is excited at a train pass-by. At equal vibration amplitude wooden sleepers emit more sound power than concrete sleepers due to its greater surface.

6. Conclusions

In the course of this project the noise emissions of different train types on a ballasted track were measured and analyzed. Therein, this work focused on the comparison of the emissions with respect to the type of sleeper.

It results that the emissions of passings on wooden sleepers are between 0,6 dB(A) and 3,1 dB(A) higher than the passings on concrete sleepers. This result controverts the common subjective believe of people living in the vicinity to railway tracks that wooden sleepers result in less noise. However, the evaluation of the psychoacoustic measure of the acoustic sharpness yields a higher sharpness of the noise on concrete sleepers. Therein, a correlation between the acoustic sharpness and perception of the neighboring people is discovered. However, the resulting A-weighted sound-pressure level that is essential for complying with the immission limits on average is 2 dB(A) lower on a ballasted track with concrete sleepers.

Acknowledgement

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