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Another Halving of Rail Freight Traffic Noise by Wheel Absorber

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ABSTRACT

By 2020 the freight traffic noise in Germany and Switzerland should be halved by changing cast iron brake blocks wheels to composite brake blocks. This means, by this time levels of 93 dB(A) should become 83 dB(A), which is the limit defined in the TSI Noise. A further reduction by half would lead to 73 dB(A), which is a part of the SBB Cargo vision for its future fleet.

The fact that this reduction is possible is shown by first results of the SBB Cargo's 5L project, where large number of suppliers helped to build a train with 16 freight wagons with a series of different noise-reducing measures (e.g. disc brakes instead of block brakes) and is currently being tested in regular traffic. Since the wheel is still the predominant source of sound emission in railway traffic, the biggest impact is reducing the wheel noise. With BVV wheel absorbers sound levels of 73 to 75 dB(A) could be achieved.

Keywords: Rail Traffic, Wheel Absorber, Reduction, Damped Wheel, 5L

1. INTRODUCTION

Wheel absorbers not only reduce the noise emissions in high-speed traffic, they also greatly reduce noise emissions in freight traffic (1).

Even if freight wagons do not fulfill the conditions of TSI Noise (2) and may no longer be used in Germany and Switzerland after 2020, there remains a demand for a further reduction of emissions. For example, SBB Cargo's vision is to use vehicles with emission levels of less than 73 dB as of 2021 (3). This 10 dB reduction to the 83 dB TSI level would decrease the noise by half. With the use of block-braked freight wagons, such a goal can hardly be achieved even with the conversion of these vehicles to K or LL brake blocks. On the other hand, the acoustically unfavorable wheel contours of block-braked wheels and the difficult mounting options for wheel sound absorbers speak in favor of the use of disc-braked and absorber-damped wheels. Application of disc brakes instead of block brakes can also benefit lifetime costs. As a result, AAE AG increased its usage of vehicles with disc brakes to reduce operating costs compared to vehicles braked with K- or LL blocks (4).

The wheels of disc-braked wheelsets can be dampened in freight traffic in a similar way as in passenger traffic. Therefore, four of sixteen vehicles of the demonstrator train of the 5L project initiated by SBB Cargo, were equipped with absorber dampened wheels from BVV (5, 6).

2. WHEEL

The wheel used is a solid freight wagon wheel with a straight web and radial wheel absorbers bolted under the running gear wheel tread. The wheel shape follows the design principles of stress balanced wheels used in high speed traffic (e.g., ICE). This leads to lower stress levels in the wheel and has also proven to be acoustically favorable. The higher load requirements compared to an ICE wheel require a little different dimensions and a higher mass.

The radial wheel absorbers are comparable to absorbers used in high speed traffic or the wheel absorbers used for Wuppertal Suspension Railway. Special hammerhead screws attached in a dovetail groove under the wheel rim connect the absorbers to the wheel.

The design and production of wheels is carried out according to the current standards (EN 13979-1, EN 13262). The wheel material is "Exzellent", a material development of BVV in terms of improved tread properties and increased mileage compared to the standard material ER8. This material is also included in the current revision of EN 13262 under the material designation ERS8 with the description that it is intended for non-clogged solid wheels and provides increased resistance to rolling contact fatigue.

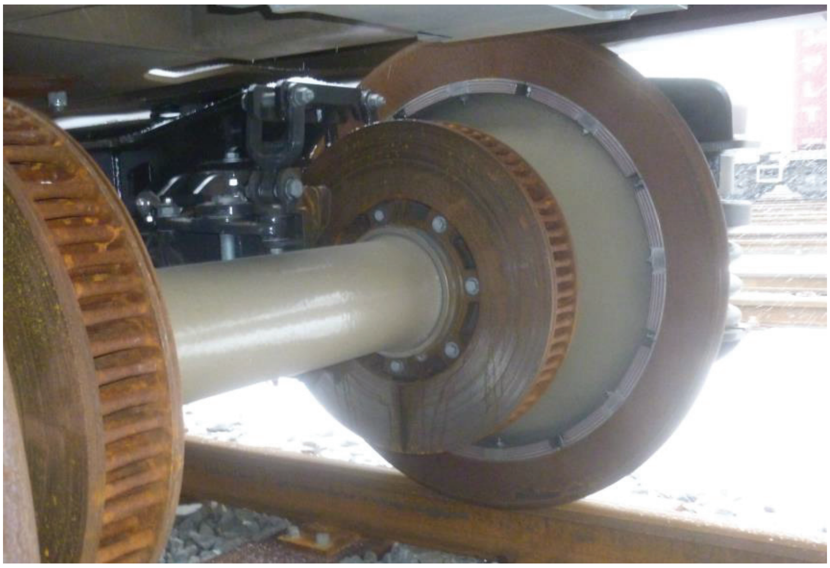


Figure 1 – This is a BVV-wheelset with wheel absorber in a vehicle of the 5L project

2.1 Wheel Absorber

Radial wheel absorbers are state of the art in passenger transport and have been used for many years in high-speed traffic (7). They are not only used for ICE vehicles in Germany, but also for vehicles in Spain (AVE) and in China.

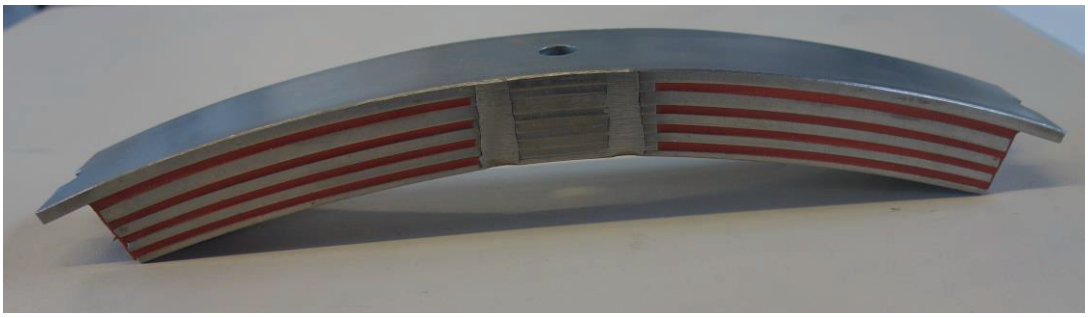


Figure 2 – This is a wheel absorber for radial damping

The absorbers are mounted below the wheel rim with special hammerhead screws in a dovetail groove. The geometry is designed to attenuate radial vibration modes which dominate the running noise. However, there is also a significant damping of axial vibration modes, such that good results can be expected even while running through switches and curves.

The absorbers have a sandwich structure comprising steel and elastomeric material. Absorbers designed specifically for the shape and the natural frequencies of the associated wheel type. The natural vibration of the wheel is transferred to the absorber, which absorbs the vibration energy.

The absorbers can be used without any problems in a temperature range of (minus) -50 °C to + 200 °C. There is a fire protection certificate according to EN45545-2: 2013-08. Requirement set R9 is met for the highest hazard level HL3.

2.2 Damping / Measurement of the Transfer Function

The damping can be shown by measuring the transfer function. The wheel is excited to vibrate and the resulting vibration acceleration is measured. The ratio of vibration acceleration to excitation force is shown frequency-dependent. Therefore a logarithmic dB scale is selected.

By measuring excitation and acceleration on the wheel tread, one can depict the radial vibration modes that dominate the rolling noise when driving straight ahead. If axial excitation and oscillation are measured on the wheel face, the behaviour of axial modes of vibration can be observed. Axial modes dominate curve squeal sound.

The absorber effect is shown by comparing the measurement on the undamped wheel and the absorber damped wheel. The wheel was suspended at the axle. The wheel was stimulated on the tread (radial) or on the front side (axial) with an impact hammer.

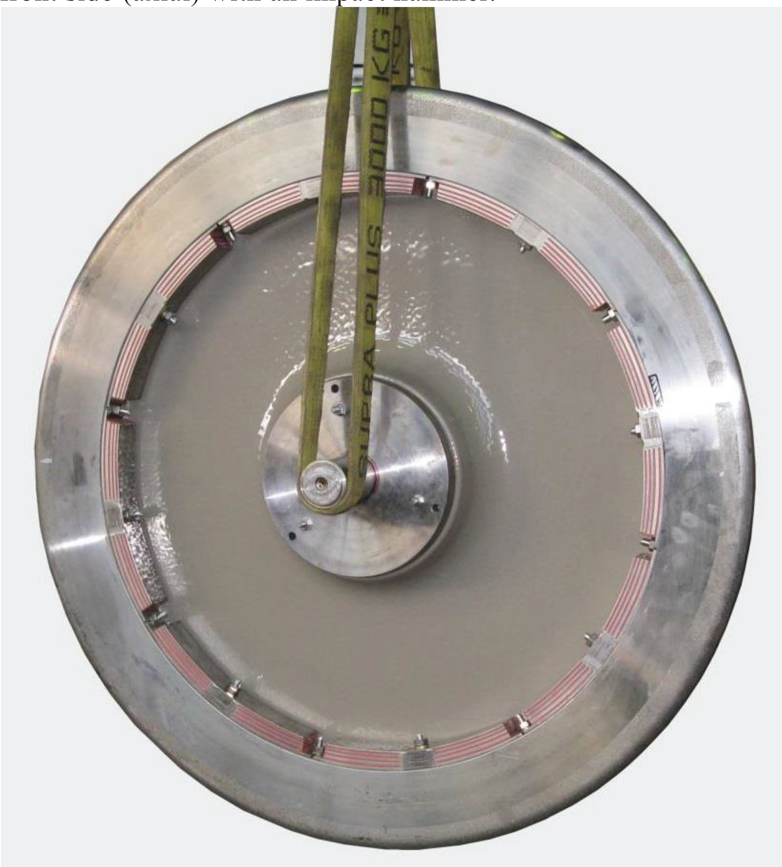
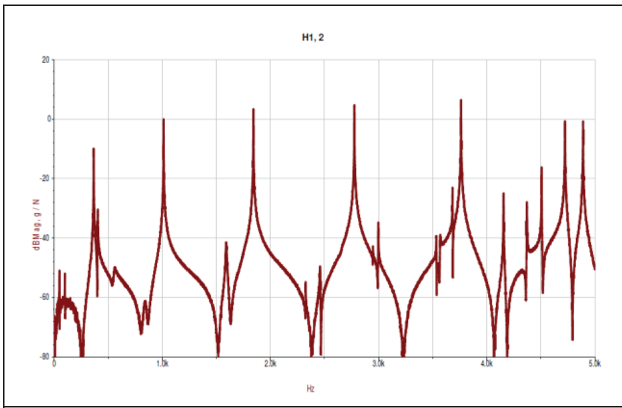


Figure 3 – Wheel with absorber, (Photo H. Neumann, IFS, RWTH Aachen)

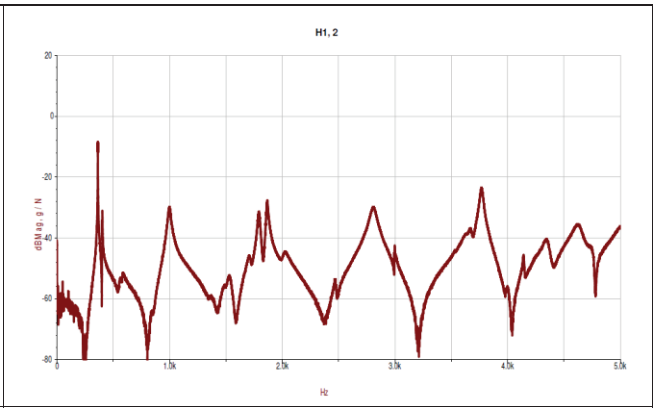
The vibration modes can be recognized as oscillation maxima in the transfer functions. The frequency of the two-knot radial mode of vibration (R2 mode) dominating the wheel's running noise is 1560 Hz, the frequency of the R3 mode is 2325 Hz.

The heights or width of the peaks provide a measure of the damping. The reduction of these peak levels indicates the absorber effect. The measurement of the transfer function is therefore also an important step in the development of absorbers for a given wheel.

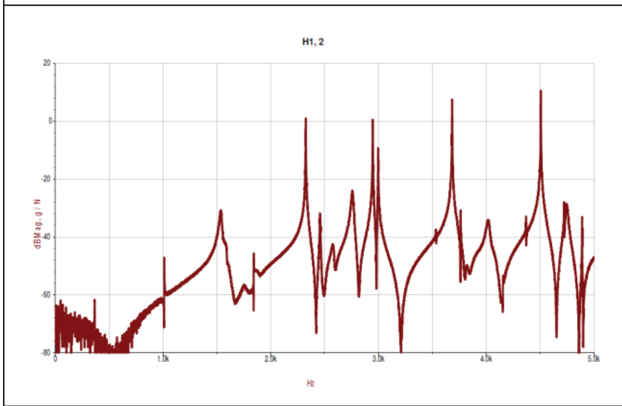
The axial and radial transfer functions of the damped and undamped wheels are shown in Figure 4.



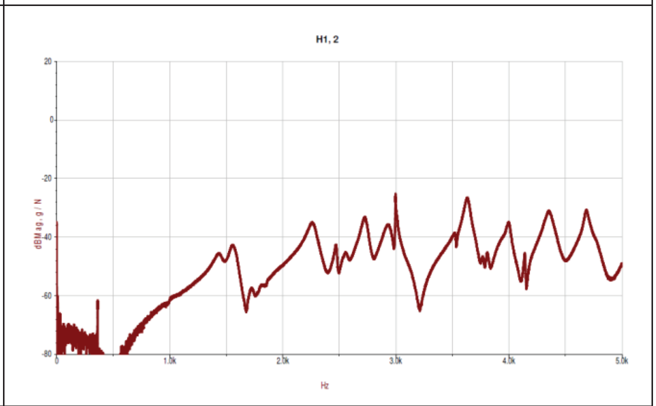
Axial excitation, wheel without absorber



Axial excitation, wheel with absorber



Radial excitation, wheel without absorber



Radial excitation, wheel with absorber

Figure 4 – Transfer functions of the BVV-5L wheel measured with impact hammer and acceleration sensor.

It can be seen that both with axial excitation and with radial excitation, the vibration modes of the wheel equipped with absorbers are significantly attenuated.

2.3 Acoustic Measurements

As a part of the 5L project, acoustic measurements were carried out while driving straight ahead and in curves. These were carried out in accordance with EN ISO 3095:2013 at three speed levels.

The acoustic level measurements were carried out at three locations in Switzerland. The pass-by-distance measurement was performed at a straight track in Kerzers, a measurement curve with radius 490 m is located in Willisau, and a curve with radius 290 m in Menznau (5, 6).

The train was assembled with 16 vehicles. Each vehicle is equipped with different components from various manufacturers (bogie, wheelset, brake, pads, coupling). Four vehicles are equipped with wheelsets from BVV (car IDs 3, 4, 8 and 10). As a reference, the SBB vehicles are equipped with Y25 bogies, wheelsets SBB Db10SA, KS Klotz brakes with JU 816M brake pads and clutches from Faiveley. Table 1 shows the components of the four vehicles in which BVV wheelsets were installed.

Table 1 – components of the vehicles with wheelsets

ID	Vehicle no.#	Bogie	Brake	Brake Pads	clutches
3	003-8	ELH	DAKO-CZ	BE_SP 140FF	Voith
10	010-3	Greenbrier	Knorr-Br.	JU707-11	Faiveley
8	008-7	WBN	Faiveley	SWG36	Faiveley
4	004-6	Tatr. poprad	Knorr-Br.	JU707-11	Faiveley

The acoustic levels are always determined for a transition between two vehicles from vehicle center to vehicle center. Since different combinations of components have been installed in different vehicles, there is no vehicle pair and thus no transition, which have only the same components. Only transitions with only one type of wheels are considered.

2.4 Pass by measurement on straight track

The levels measured on the straight track can be found in Table 2. The two transitions ID 10/8 and ID 8/4 have only BVV wheelsets. The reference are that Y25 bogies of the SBB vehicles 15 and 16, the vehicles at which no flat spots occurred during the test drives.

Table 2 – Pass By Levels LpA in dB, (*) influenced by flats, Y25 wheelsets 15/16 as reference

M#, no. of measurement	Driving direction	v km/h	L_{pA} (dB) ID 10/8	L_{pA} (dB) ID 8/4	L_{pA} (dB) ID 15/16
M05	2	76.4	74.5	73.9	79.2
M07	2	76.9	74.5	74.7*	77.6
M09	2	77.3	74.6	74.8*	77.6
M04	2	96.3	74.1	73.3	79.3
M11	2	98.0	74.0	74.2*	77.0
M08	1	98.1	74.2	74.4*	80.5
M13	2	98.6	74.0	74.1*	77.9
M02	2	99.9	74.4	73.5	80.3
M01	2	10.,5	74.0	73.0	80.8
M06	1	118.0	74.1	74.4*	81.0
M12	1	118.7	74.2	74.6*	82.2
M10	1	120.3	74.1	74.9*	82.0
M03	1	120.9	74.1	73.7	81.9

The levels have been converted to a speed of 80 km/h for comparability. A correction to apl/vehicle length was not done in this compilation (6), since all vehicles are of the same type and length and this is not necessary for a comparison of the level values with each other. From the M06 drive, emergency stops have caused flaps in the area of the DG 4/7 transition, which also led to faults in the DG 8/4 interval. In these cases, at the DG 8/4 transition greater LpA levels than 74 dB have been determined (*), while for the first rides, approximately 1 dB lower levels - all below 74.0 dB - have been determined.

The average levels of the three speed levels are shown in the following table:

Table 3 – Pass By Levels LpA in dB, without apl correction

Levels, Levels of ID8/4 include influence of flats

v km/h	L_{pA} (dB) ID 10/8	L_{pA} (dB) ID 8/4	L_{pA} (dB) ID 15/16
80	74.5	74.5	78.1
100	74.1	73.8	79.3
120	74.1	74.4	81.8

In the TSI Noise (2), acoustic levels for freight wagons are now related to a reference APL value of 0.225 m^{-1}. The previously applicable scale is no longer be used. According to TSI NOI 2014, the measured level is changed by the correction term -10 log (APL_Wagon/APL_Ref).

The wagons used in the 5L project have a length of 20.05 m. This corresponds to an APL of 0.1995 m^{-1}. For comparison with TSI levels, therefore, a correction term of +0.52 dB must be added. Values to be used for assessing conformity are then:

Table 4 – Pass By Levels LpA in dB, APL corrected,

Levels of ID8/4 include flat influence

v km/h	L_{pA} (dB) ID 10/8	L_{pA} (dB) ID 8/4	L_{pA} (dB) ID 15/16
80	75.0	75.0	78.6
100	74.6	74.3	79.8
120	74.6	74.9	82.3

The levels of BVV-wheeled vehicle transitions are rounded up to TSI levels of 75 dB. Looking at the transition ID 4/8 and ignoring rides with the influence of flats of the adjacent transition, gives a value of 74 dB, which would however be based on very few measurements.

3. Comparison with TSI Acceptance Measurements

To classify the determined level, it is compared with levels of other freight vehicles. This is based on a report commissioned by the German Federal Environmental Agency (UBA) and written by MBBM, in which the noise emission from rail vehicles was recorded and compiled during TSI noise-related certification during a survey (8).

Figure 5 shows a representation of all registration levels of freight wagons from this report, in which the 5L levels have been added, extending the field of measured points downwards.

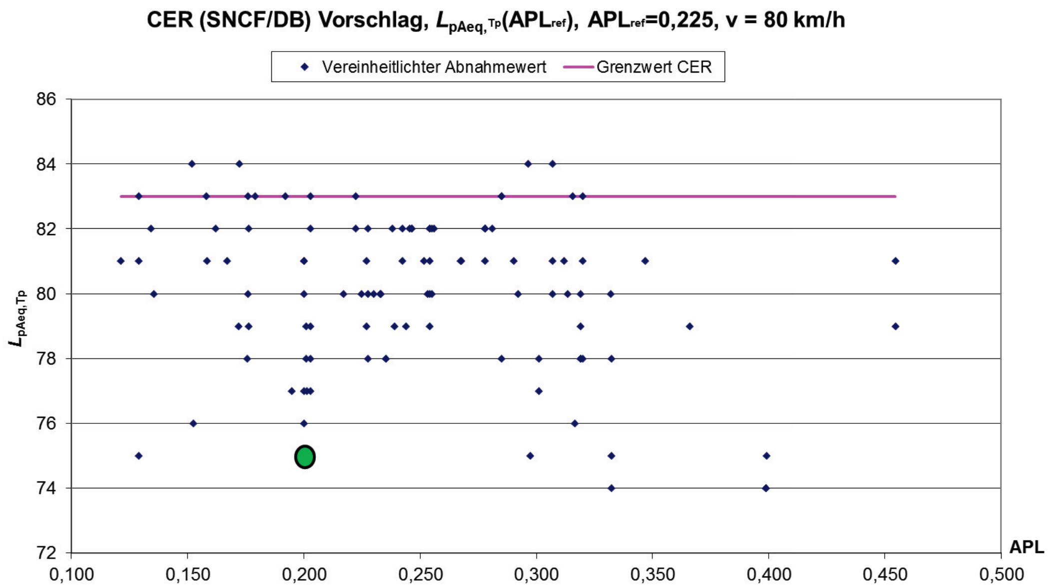


Figure 5 – Overview of TSI levels from the UBA report (8) supplemented by one point for the level of the 5L project (75 dB / APL 0.2).

This shows that it is possible to reduce the passing levels of freight wagons well below the TSI values. It makes sense to encourage the use of such low-emission technologies with a noise-related train path pricing system, in which particularly quiet cars have to pay significantly less (9).

4. CONCLUSIONS

In SBB Cargo's 5L project, an innovative freight train was put together. Wheelsets from Bochumer Verein Verkehrstechnik GmbH were used in four wagons, which are equipped with absorber-damped wheels. The lowest pass-by levels LpA were measured from 73 dB to 75 dB at the vehicle interchanges with BVV wheelsets corresponding to TSI levels of 74 dB to 75 dB. The results show, that a further reduction of freight traffic by half, from 83 dB to 73 dB, is possible, when using disc-braked and absorber-damped wheelsets.

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