_psiacoustic
Umweltforschung und Engineering GmbH

Field Test STRAILastic_A_inox
Measurement Location Deutsch Wagram/Austria

Inspection Report

carried out by order of
KRAIBURG Elastik GmbH

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1 TASK AND MEASUREMENT PROCEDURE

The STRAILastic_A_inox rail damper developed by the company KRAIBURG Elastik GmbH has to be evaluated acoustically in the course of a measurement campaign during on-going operation.

A measurement section at the Nordbahn at Deutsch Wagram, track kilometer 14.4 near Vienna, was chosen for the investigation. This investigation report provides information about the acoustic effect (gain reduction) of the examined damping elements. Generally, velocities from 60 to max. 120 km/h are reached at the chosen track section. During this investigation, we mainly focused on those pass-bys which pass by the measurement section with velocities exceeding ≥100km/h since according to the manufacturer, the highest gain reductions can be expected this way. Furthermore, the damper was developed especially for that velocity range.

The investigation was separated into two stages (reference measurement without measures and measurement with installed rail web dampers. In the reference measurement (6 May - 21 May 2013) we defined the current acoustic situation. The second series of measurements (22 May - 8 June 2013) was carried out at the same track section and was done analogously to the reference measurement.

The sounds of the trains which passed by during the two measurement series (reference measurement and subsequent measurement with STRAILastic_A_inox elements installed) were recorded with the mobile, automatic, 8-channel measuring system acramos®. That measuring system records and analyses every pass-by of a train autonomously.

Additionally, the Track Decay Rate (TDR) was calculated from the measured horizontal and vertical accelerations using the PBA method. By doing so, we could determine the influence of the respective superstructure on the sound pressure level occuring during the pass-by and compare the results.

2 EXAMINED SYSTEM STATUSES

2.1 Initial state

The examined, double-track measurement section is situated at the Nordbahnstrecke in Deutsch Wagram, Austria, at track kilometer 14.4, on a straight track (agricultural area) without any relevant buildings (free sound propagation). The section is ideally suited for sound measurements, since no buildings or overgrown slopes (topography) interfere with the free sound propagation. The measurement track (track 2) has a superstructure with concrete sleepers with UIC 60 rails.

Abb. 2-1 Meaurement location - surroundings

2.2 STRAILastic_A_inox elements

The product STRAILastic_A_inox by KRAIBURG Elastik is mounted to the rail web and is supposed to reduce the vibrations of the rail which arise when a wheel of a train runs over the rail. Therefore, it should have a positive effect on the acoustic emission of the rail. This effect is mainly achieved by increasing the Track Decay Rate. The STRAILastic_A_inox elements consist of a bend-proof metal piece which is covered by highly-vibration-reducing rubber and are pressed onto the inner and outer rail web with clamps.

Figure 2-2 shows a STRAILastic_A_inox element mounted to the rail.

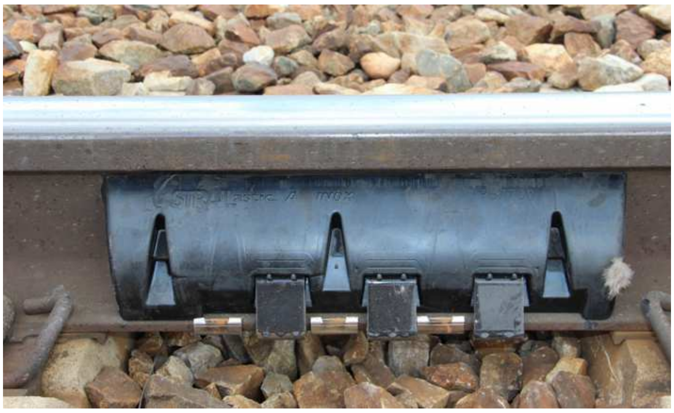


Figure 2-2 STRAILastic_A_inox application example

3 MEASUREMENT CONCEPT

3.1 Measurement setup

Figure 3-1 and Figure 3-2 schematically show the measurement setup. The microphone M1 is positioned at a 7.5 m distance to the track axle of the measurement track (track 2) and at a height of 1.2m.

Two inductive wheel sensors are attached to the meaurement track (track 2, direction Gänserndorf). Wheel sensor R1 is situated inside the track section and allows an exact allocation of the respective axle to the measured sound level. Wheel sensor R2 is situated outside the measurement section and acts as a trigger for the automatic measuring system (this means that the measurement is started before the train reaches the measurement section).

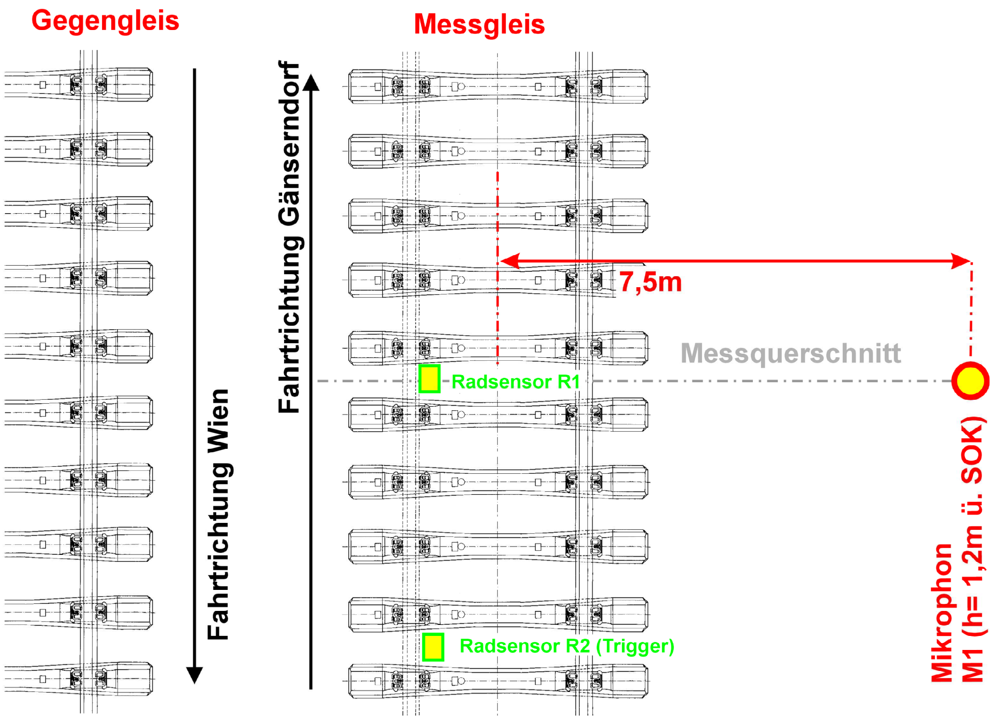


Figure 3-1 schematic drawing of the measurement section

Figure 3-2 Overview of the track section

When the train is passing by, the sound emission occuring at the track section is measured at microphone position M1 and the axle signals of the inductive wheel sensor are recorded parallely. With the help of the axle signal (= axle position), the measured emissions are allocated to the respective positions of the individual wheel or the bogey. The measured axle pattern is entered into an internal data base and then the train category (e.g. freight train, passenger train, etc.) is determined.

Tab. 3-1 Measurement setup field test STRAILastic_A_inox

CH	Name	Typ	Position
1	M1	Mikrophone	Q1 7.5 m from track axle/1.2m above rail
3	V1	Acceleration	Q1 rail vertical
4	H1	Acceleration	Q1 rail horizontal
5	S1	Acceleration	Q1 sleeper vertical
7	R1	Wheel sensor	Q1 measurement section
8	R2	Wheel sensor	Q2 trigger signal

The following measurements and parameters were recorded and analysed:

A-weighted sound pressure level at pass-bys (dependant on velocity) for each train category

The average A-weighted sound pressure levels during pass-bys $L_{A,pb\ (v)}$ (dependant on velocity) are calculated from the individual values of each train that passed by.

Linear spectrum of the sound pressure levels at pass-bys for each train category

The spectral change in the sound caused by the measure (STRAILastic_A_inox) elements) can be seen from the spectrum of the sound pressure level during pass-bys for each train

3.2 Track Decay Rate

The Track Decay Rate is used in TSI Noise as an index for the sound emission of the superstructure. The Track Decay Rate describes the reduction of rail vibrations per running meter of rail [dB/m] in the individual third-octave bands. This means that the higher the level becomes, the lesser the rail vibrates. Thus, the Decay Rate provides information about the acoustic nature of the track. The vertical and horizontal Decay Rate is measured through puls excitation of the (unladen) track (impuls-hammer method).

According to TSI Noise, tracks are suited for certification measurements regarding their vibration behaviour (and thus, their sound emission behaviour) if the measured vertical and horizontal Decay Rates exceed the limits shown in figure 3-3 s.

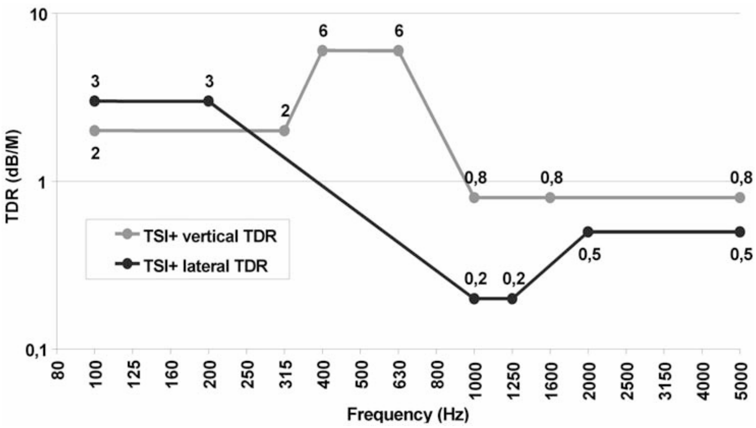


Figure 3-3 Limits of horizontal and vertical Decay Rates [Source: [1])

As an alternative to the method described in TSI Noise (puls excitation of the unladen track using an impulse hammer), the Dutch research institute TNO developed the software package PBA (pass-by-analysis) which allows to calculate the Track Decay Rate, the transfer function, the overall roughness of the wheel and rail and consequently the sound level for the pass-by of a train (Figure 3-4). As input, the software needs the sound signal of a pass-by, the signals of a vertical and horizontal accelerometer, the vehicle geometry and the velocity.

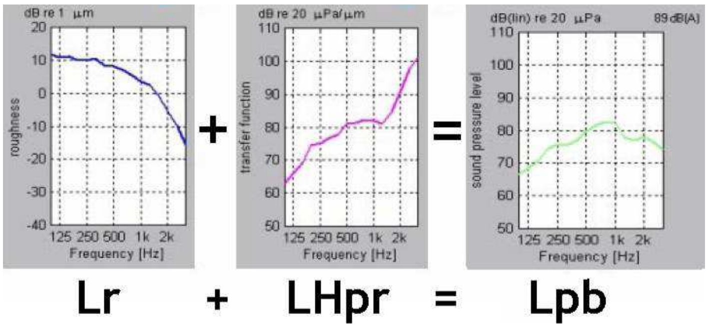


Figure 3-4 Separation of sounds acc. to STAIRRS (Source: de Beer/Jansen/Dittrich 2002)

For determining the vertical and horizontal Track Decay Rate, PBA requires the signal of the wheel sensor, the velocity, as well as the vertical or horizontal acceleration signals.

The above procedure was used in this case.

4 METEOROLOGIC CONDITIONS

The meteorologic conditions were constantly gathered during the reference measurement and as well as during the measurements with the installed STRAILastic_A_inox dampers and the respective values were recorded for each pass-by. Figure 4-1 shows the respective maximum and minimum temperatures for each day, of those pass-bys which were used for the evaluation.

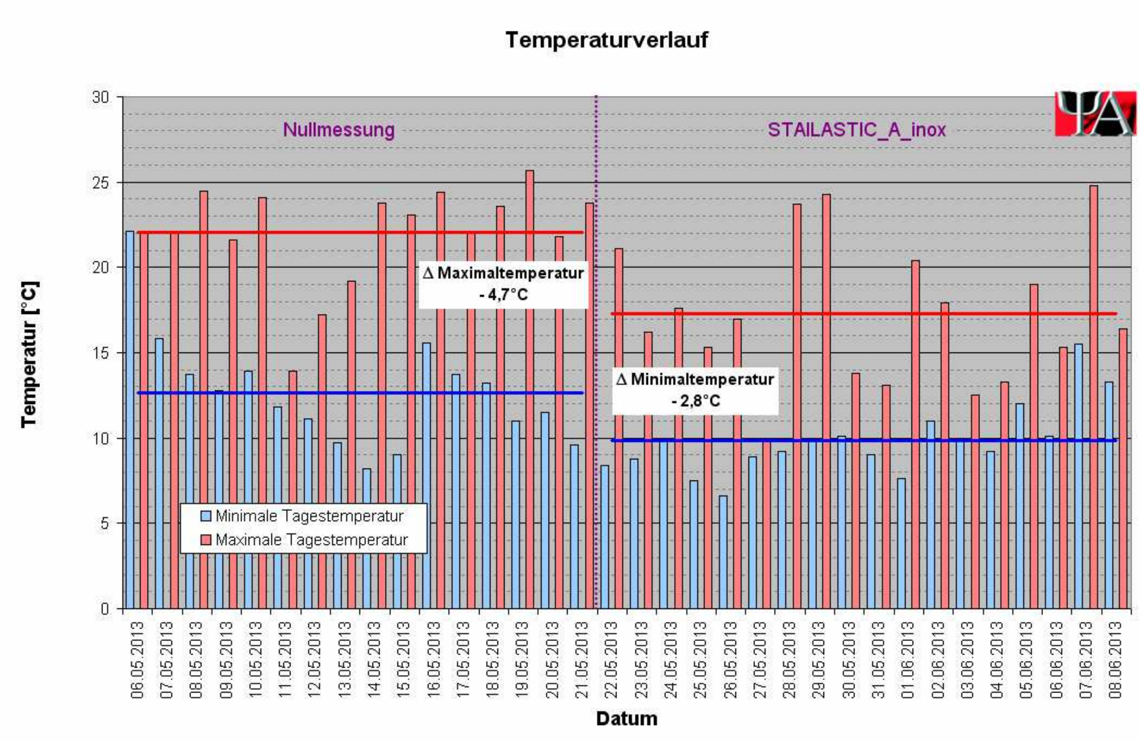


Figure 4-1: Daily minimum and maximum temperatures during the measurement period

The average temperatures during the reference measurement exceeded for both the maximum and the minimum values the temperatures of the subsequent measurement with the STRAILastic_A_inox damping elements.

5 MEASUREMENT RESULTS

5.1 Track Decay Rate

For a better evaluation of the acoustic measurement results, not only the actual measurements regarding sound emission were determined, but also the vibration behaviour of the rails in the measurement section. The vertical and horizontal Track Decay Rate (TDR) is used as a parameter for the vibration behaviour and for the sound emission of the rail, as it is defined in ON EN ISO 3095 [2] and TSI-CR-Noise [1].

For the measurement track (track 2), the vertical and horizontal TDR for the loaded track was determined using the software package PBA which was developed by Dutch research institute TNO.

Figure 5-1 shows the results of the vertical TDR. Before the STRAILastic_A_inox elements were installed, the vertical TDR had already greatly exceeded the TSI-CR-Noise limit at all frequencies.

By installing the damping elements, the TDR was increased at all frequencies. Especially in the frequency range of 1 to 4kHz, it could be increased by up to10dB.

Figure 5-2 shows the results of the horizontal TDR. In the reference measurement the TDR already exceeded the limit. After installing the STRAILastic_A_inox elements, a significant increase in the TDR could be observed in the frequency range >315Hz (by up to 7dB). In the range of <315 Hz, only minor increases could be achieved.

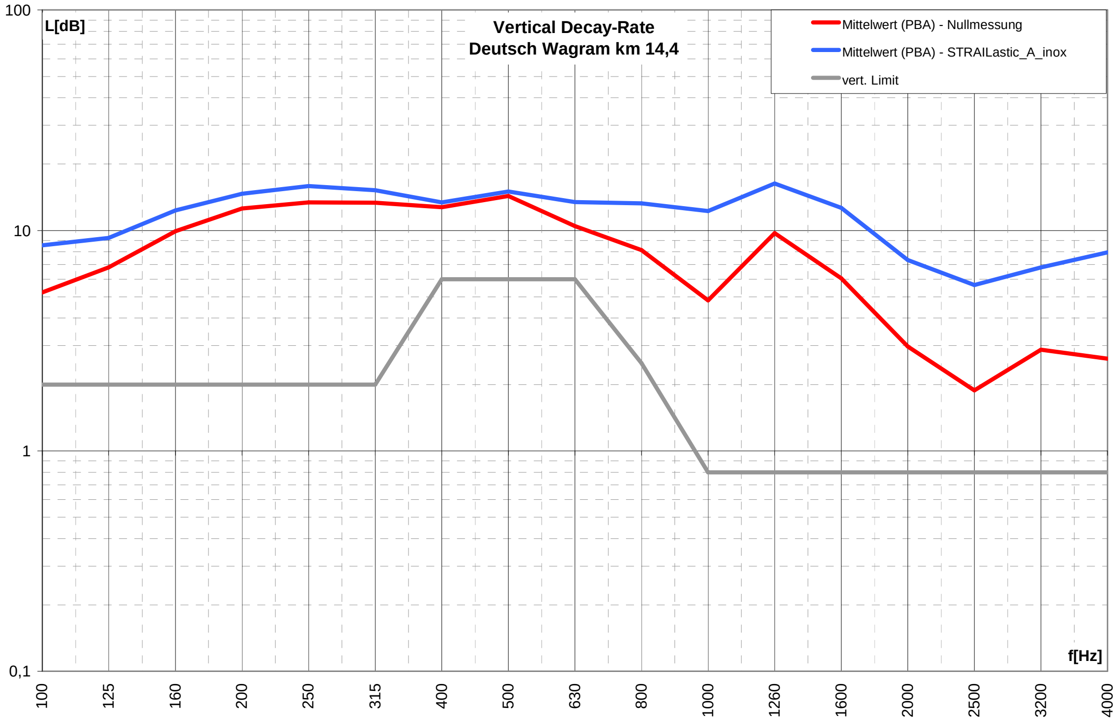


Figure 5-1: vertical TDR, summary; Deutsch Wagram km 14.4

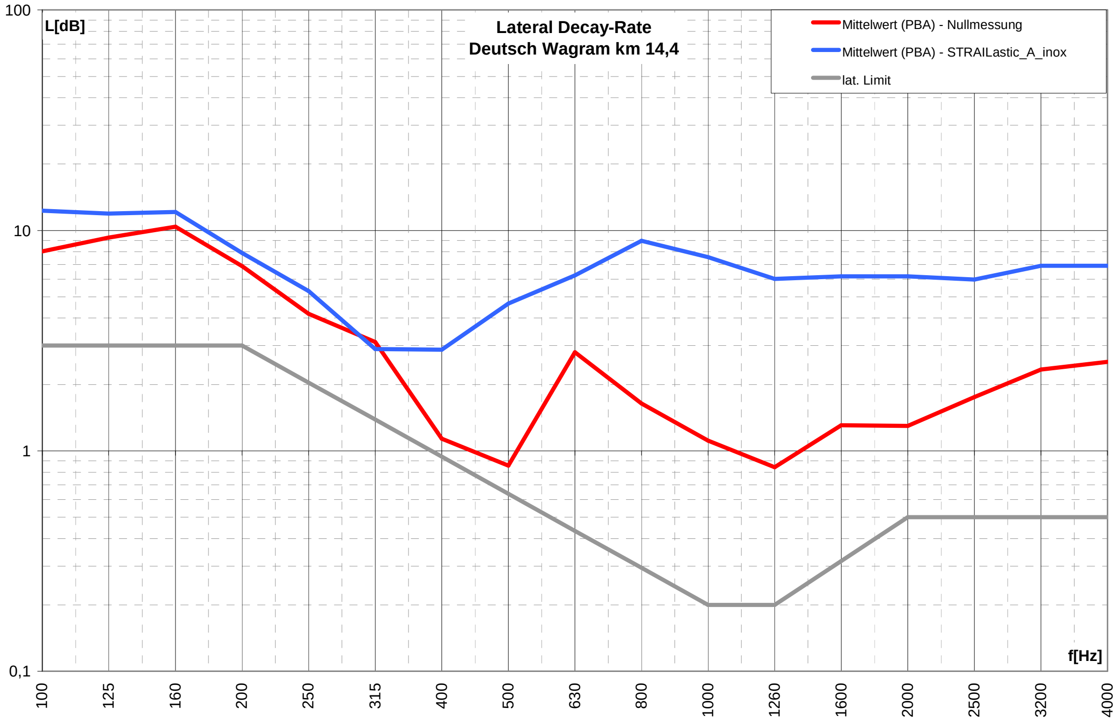


Figure 5-2 horizontal TDR, summary; Deutsch Wagram km 14.4

5.2 A-weighted sound pressure level at pass-bys $L_{p,A,pb}$ (v)

Table 5-1 shows the number of trains recorded and used in this investigation according to train categories and roughness of the wheel with velocities ≥ 100km/h.

We only used pass-bys where the deviations between the maximum and minimum values of the measured velocity (when passing by) were below <5km/h. Thus, trains slowing down or accelerating were not considered.

Tab. 5-1 No. of measured trains for each category

Train Category	Ref. Msmt.	STRAILastic_A_inox
RZ-mix	20	24
Passanger (smooth)	142	174
Passanger (rough)	221	191
Total	383	389

In order to get an individual value (which is independant of the velocity) of the effect of STRAILastic_A_inox dampers for each train category, all pass-bys were set to 100 km/h and an average A-weighted sound pressure level at pass-bys was determined. Figure 5-3 shows the average values for each train category for both stages (reference measurement, STRAILastic_A_inox elements).

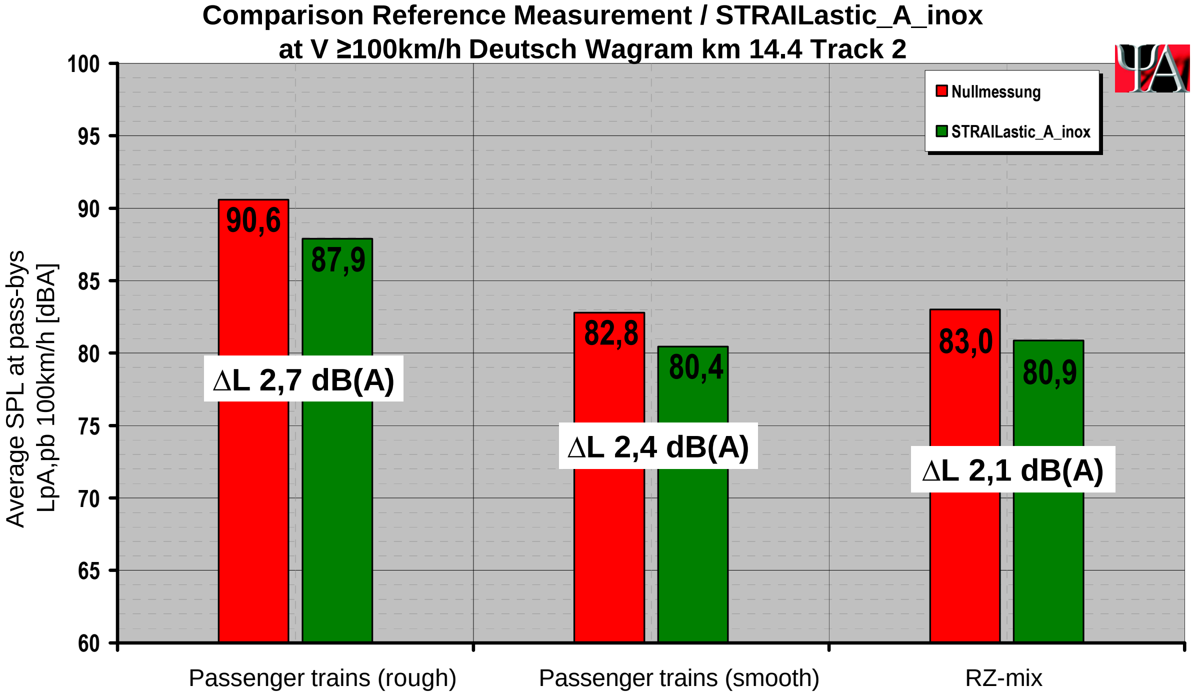


Figure 5-3 Average A-weighted sound pressure levels at pass-bys (referring to 100km/h, comparison reference measurement/STRAILastic_A_inox

Below you can find the respective pass-bys (independent of velocities) ≥ 100km/h.

Figure 5-4 shows the A-weighted sound pressure levels at pass-bys of the category Rz-mix (passenger trains with different braking systems - grey iron as well as composite soles or disc brakes). When you compare the measurement results of the reference measurement with those obtained when the STRAILastic_A_inox elements were installed, you can see a reduction of up to 2dB at a height of 1.2 m at measurement position 1. However, it has to be considered that in this category only a low number of pass-bys could be evaluated (v ≥ 100km/h).

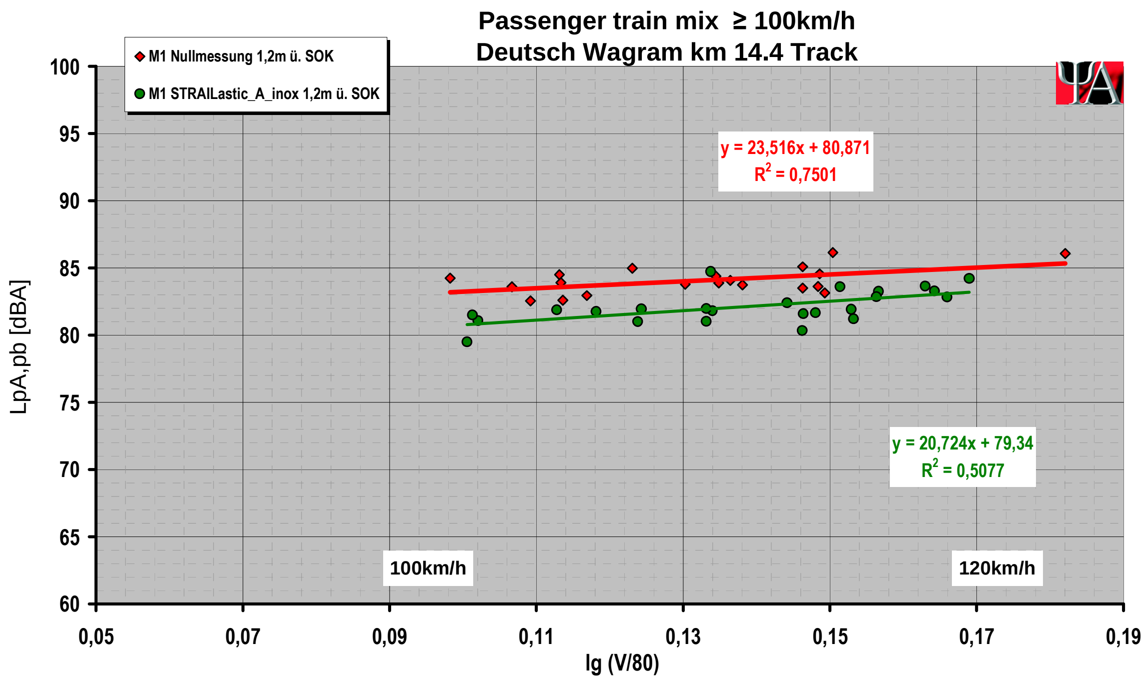


Figure 5-4 A-weighted sound pressure level at pass-bys, RZ-mix ≥ 100km/h in M1(7.5m/ 1.2m) with and without STRAILastic_A_inox

Figure 5-5 shows the A-weighted sound pressure levels at pass-bys of the category passenger train (smooth wheels) for the reference measurement without measures, as well as for the situation with STRAILastic_A_inox elements. This category represents modern train sets for regional transport with wagons which have disc brakes and smooth wheels.

By installing STRAILastic_A_inox elements, a gain reduction of 2 to 2.5 dB could be achieved at microphone position M1.

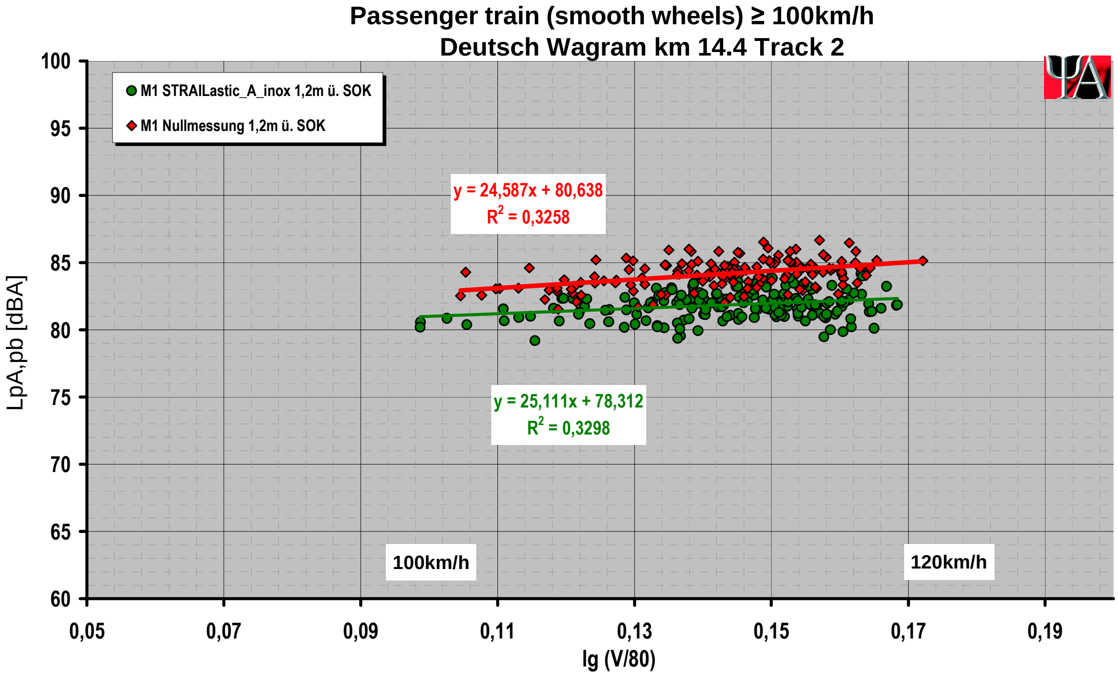


Figure 5-5 A-weighted sound pressure level at pass-bys, passenger train (smooth rails) ≥ 100km/h in M1(7.5m/1.2m) with and without STRAILastic_A_inox

Figure 5-6 shows the A-weighted sound pressure levels at pass-bys of the category passenger trains (rough wheels). When you compare the results of the reference measurement with those obtained when the STRAILastic_A_inox elements were installed, a reduction of >2.5 dB can be observed at a height of 1.2m at measurement position M1.

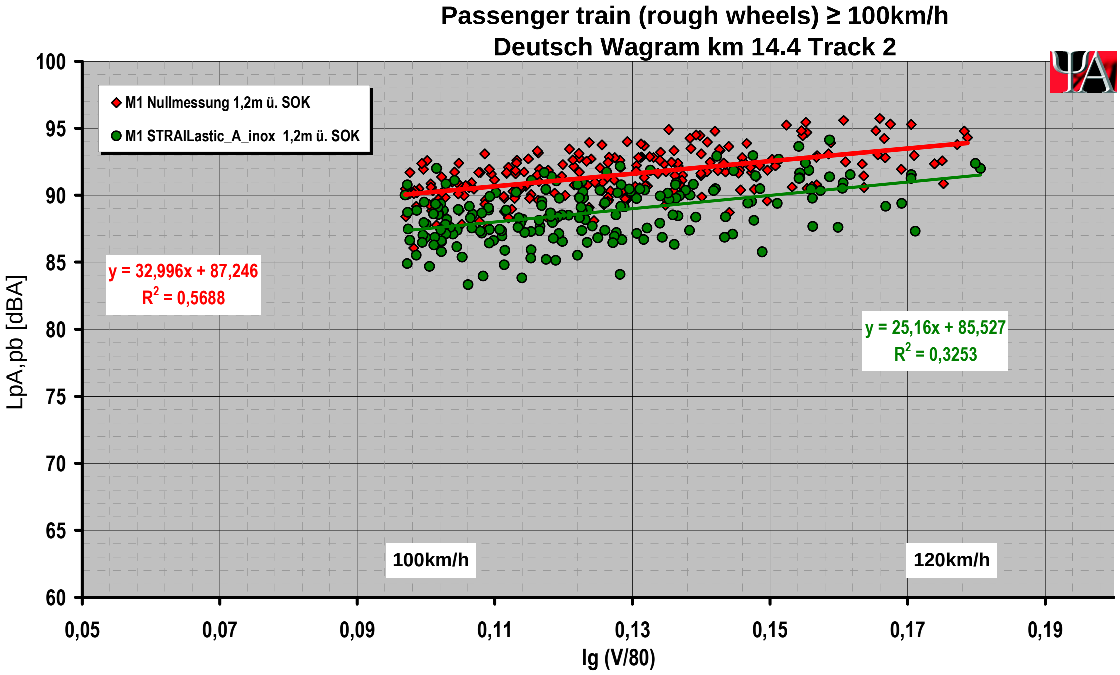


Figure 5-6 A-weighted sound presurelevel at pass-bys, passenger train (rough wheels) ≥ 100km/h in M1(7.5m/1.2m) with and without STRAILastic_A_inox

5.3 Average linear spectra of SPL at pass-bys $L_{pb\ (f,v)}$

The following figures show the linear spectra of sound preure levels (third octave band level spectra). Those diagrams (which are separated by system statuses) show the average third octave band level spectra of the pass-bys of all vehicles which passed by with velocities of ≥ 100 km/h within the respective train category.

Figure 5-7 shows the average linear third octave band spectra for the category passenger train (smooth wheels).

At microphone position M1, the values of the reference measurement fall below the limit by up to 3.4 dB (with the exception of the values of the one-third octave centre frequency of 400Hz, in which idential results were reached during both stages).

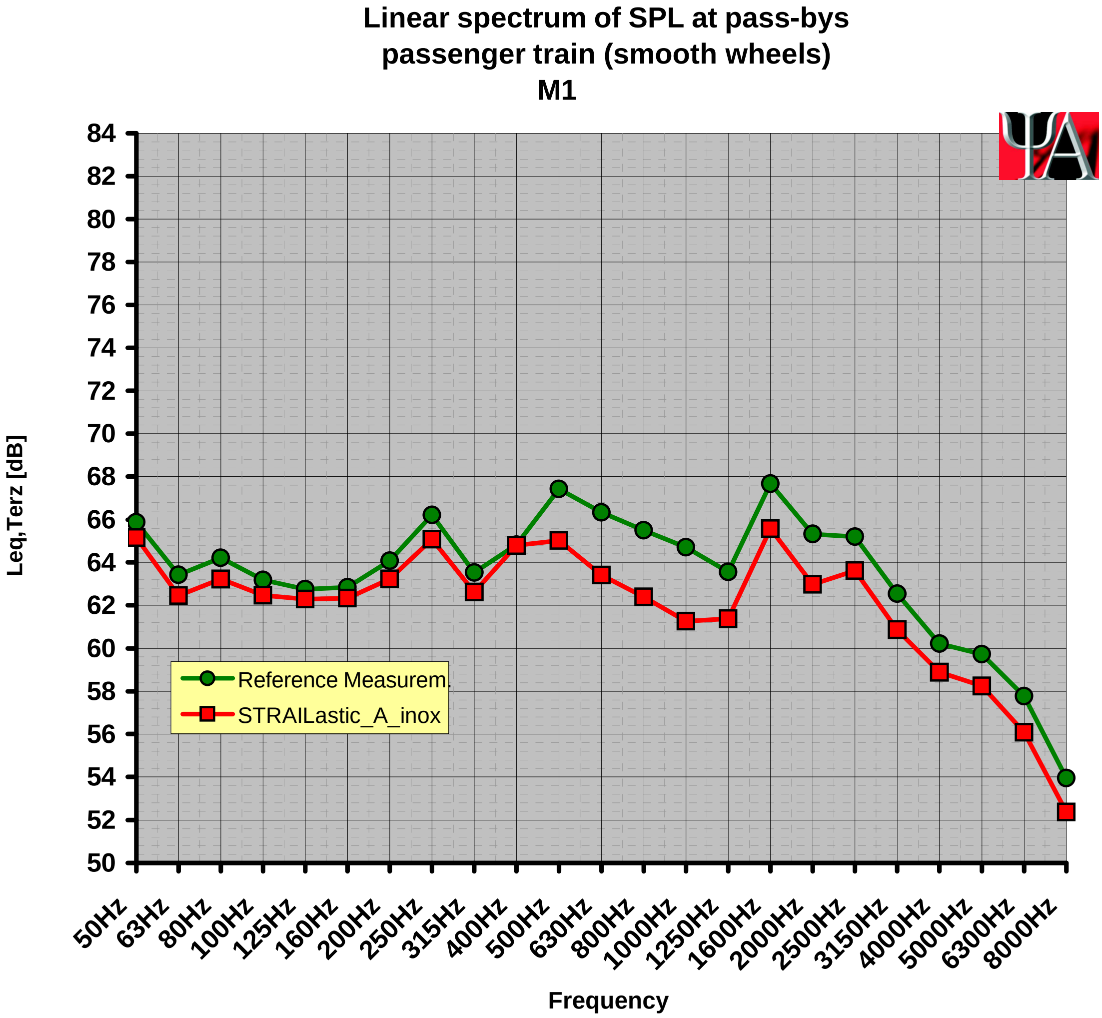


Figure 5-7 average linear spectrum of SPL at pass-bys with and without STRAILastic_A_inox, trains of the passenger train category (smooth wheels) for microphone position M1(7.5m/1.2m)

Figure 5-8 shows the average linear third octave band spectra for the passenger train category (rough wheels).

At microphone position 1, the third octave levels for both stages are almost identical for the frequency range between 200 and 400 Hz. At frequencies of <200 Hz, the values fall below those of the reference measurement by approx. 1dB. In the frequency range of >400Hz a reduction of the third octave level by up to 4 dB could be achieved by installing the STRAILastic_A_inox elements.

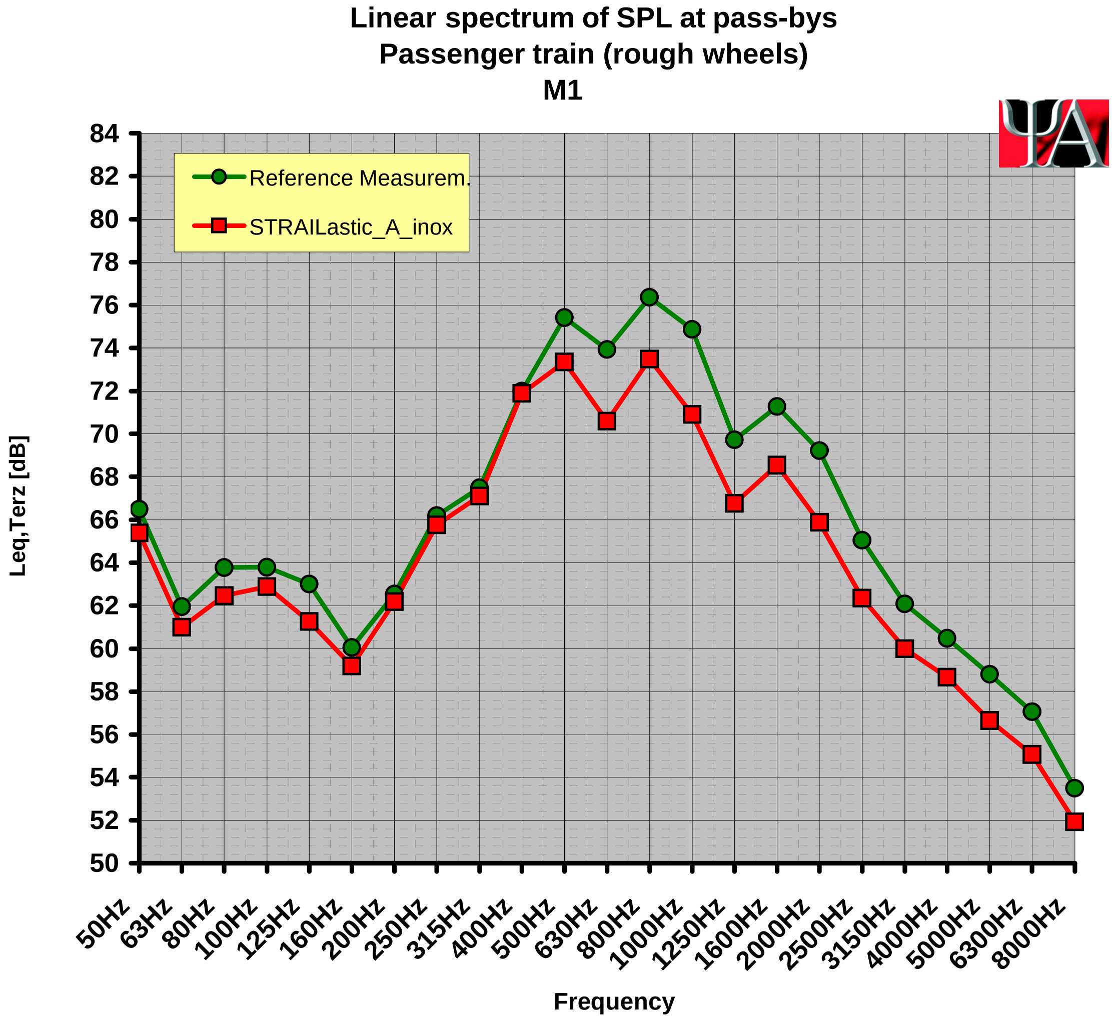


Figure 5-8 average linear spectrum of SPL at pass-bys with or without STRAILastic_A_inox, trains of the passenger train category (rough wheels) for microphone position M1(7.5m/1.2m)

Figure 5-9 shows the average linear spectra for the thord octave level for the category RZ-mix

When you compare the results of the reference measurement with those obtained when the STRAILastic_A_inox damping elements were installed, gain reductions of up to 3 dB could be achieved throughout the whole frequency range.

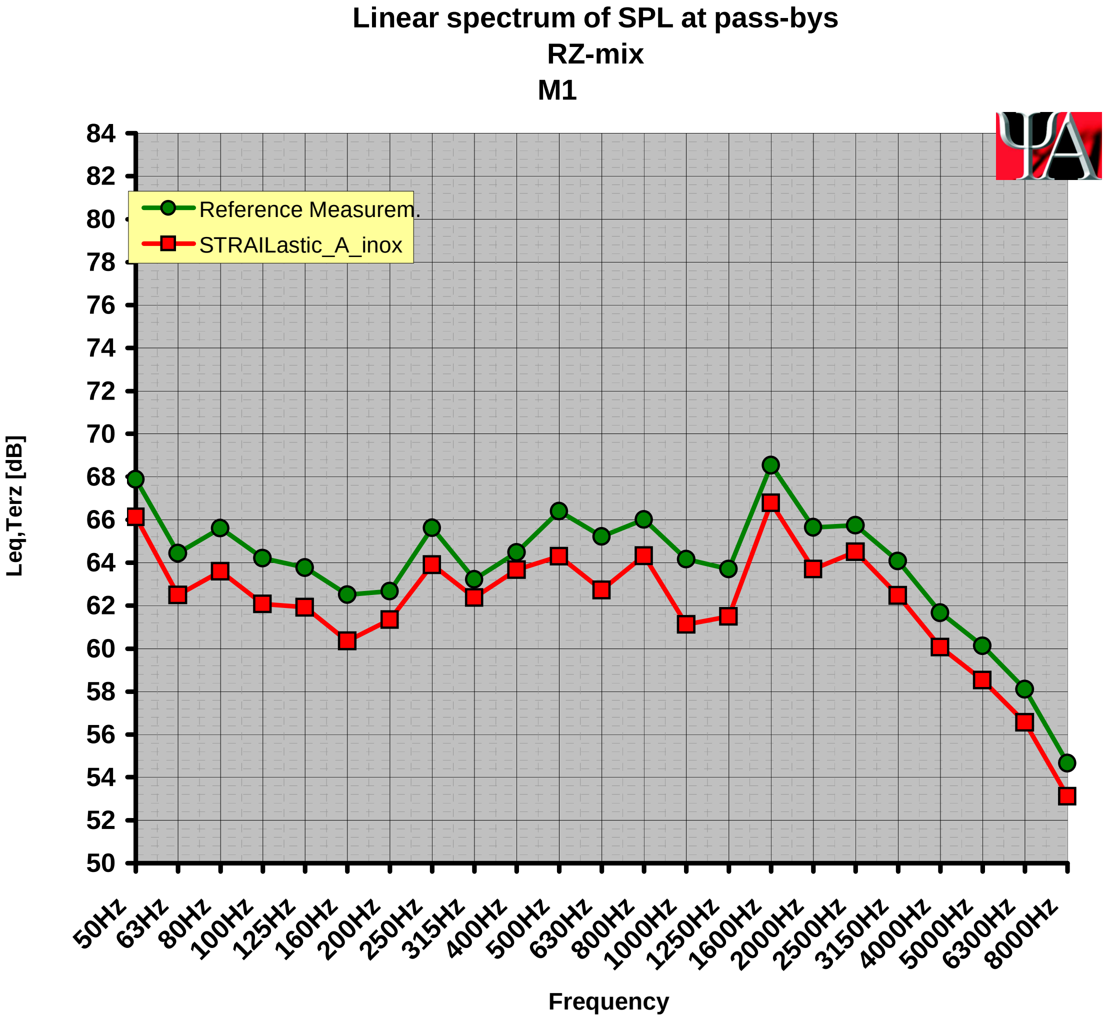


Figure 5-9 average linear spectrum of SPL at pass-bys with and without STRAILastic_A_inox, trains of the RZ-mix category for microphone position M1(7.5m/ 1.2m)

Figure 5-10 shows the average linear spectra of third octave levels for the freight train category. Since there are no pass-bys >100 km/h in this category, all pass-bys were used for the calculation of the average third octave level.

When you compare the results of the reference measurement with those obtained when the STRAILastic_A_inox damping elements were installed, gain reductions of up to 3.4 dB could be achieved throughout the whole frequency range.

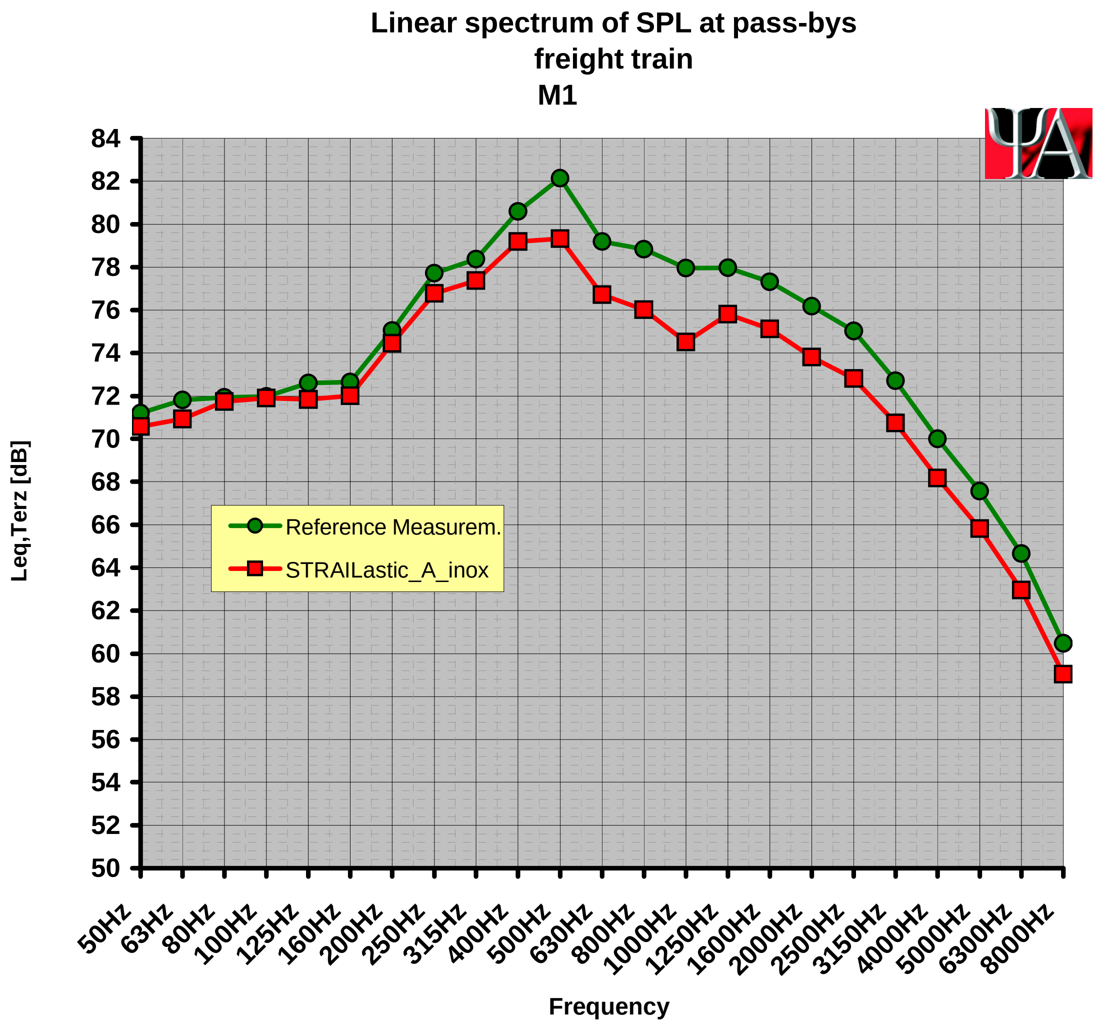


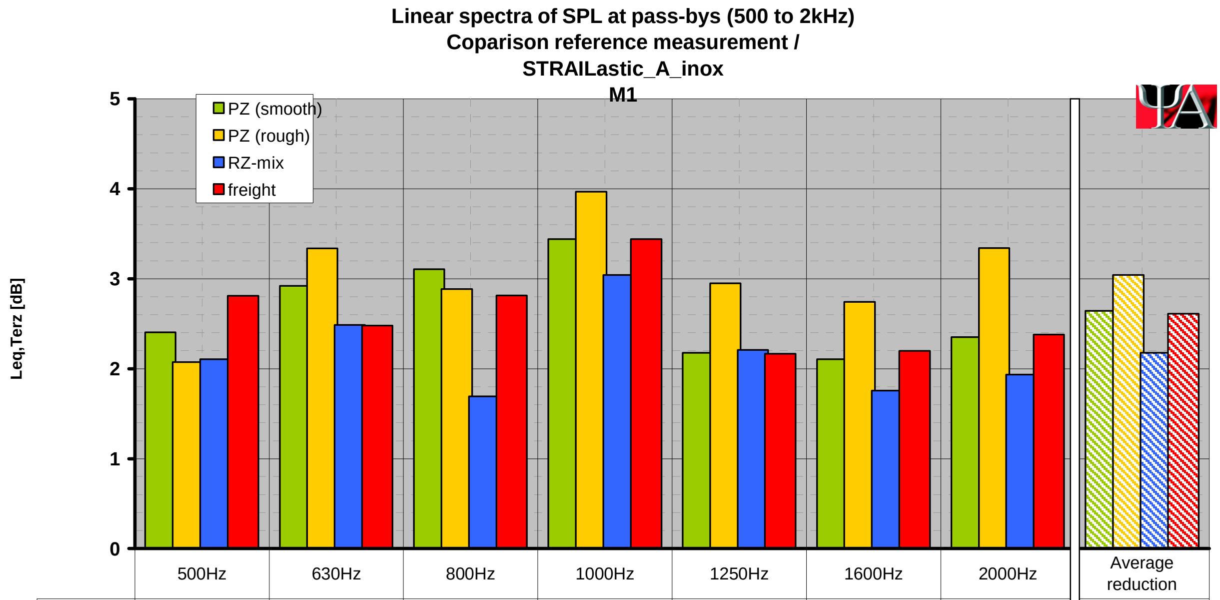
Figure 5-10 average linear spectra of SPL at pass-bys with and without STRAILastic_A_inox , trains of the freight train category for microphone position M1(7.5m/1.2m)

5.3.1 Reductions in the frequency range between 500Hz to 2kHz

The results of the linear spectra of SPL at pass-bys show that the damping elements achieve their best results for all train categories in a frequency range from 500 Hz to 2kHz. That is a frequency range relevant for the human hearing. In the following, this range will be analysed in more detail.

Figure 5-11 shows the gain reduction of all train categories for the relevant frequency range. Since no pass-bys of >100 km/h of freight trains could be measured, all existing pass-bys were used for this evaluation.

You can see that the highest gain reduction could be achieved with passenger trains with rough wheels at 1 kHz (reduction by 4 dB). Generally, in all train categories the biggest effect was achieved at this frequency.



	500Hz	630Hz	800Hz	1000Hz	1250Hz	1600Hz	2000Hz	Average reduction
PZ (glatt)	2,4	2,9	3,1	3,4	2,2	2,1	2,4	2,6
PZ (rau)	2,1	3,3	2,9	4,0	2,9	2,7	3,3	3,0
RZ-mix	2,1	2,5	1,7	3,0	2,2	1,8	1,9	2,2
Güter	2,8	2,5	2,8	3,4	2,2	2,2	2,4	2,6

Frequency [Hz]

Figure 5-11 average gain reduction for each category in the third octave bands 500Hz- 2kHz of all pass-bys for microphone position M1(7.5m/1.2m)

The average gain reduction for passenger trains with smooth wheels in the frequency range of 500Hz to 2kHz is approx. 3dB. For passenger trains with rough wheels and freight trains, a average reduction of 3.0 and 2.6 dB respectively could be achieved in that frequency range. In the Rz-mix category, the lowest gain reduction of approx. 2.2 dB could be observed.

Thus, the average gain reduction for all train categories is 2.6 dB in the frequency range of 500 Hz to 2kHz.

6 EVALUATION

Compared to the bare track, the installation of STRAILastic_A_inox rail web dampers achieved a gain reduction in all examined train categories.

The highest A-weighted gain reductions of 2.7 dB(A) could be measured in the velocity range of ≥100km/h in the passenger train category (rough wheels). In the Rz-mix category, gain reductions of 2.1 dB could be measured and in the passenger train category (smooth wheels), gain reductions of 2.4 dB could be achieved. After the installation of the rail web dampers, the average A-weighted sound pressure level at pass-bys could be reduced by approx. 2.4 dB for velocities ≥100km/h.

The average, linear spectra of third octave levels at pass-bys show that the STRAILastic_A_inox elements have the biggest effect in the frequency range of 500Hz to 2kHz. In this frequency range, the average gain reduction is approx. 2.6 dB for all train categories.

Table 6-1 shows the number of measured trains per category as well as the respective gain reduction caused by the installation of the STRAILastic_A_inox elements (=acoustic effect) for velocities ≥100km/h. The gain reductions are valid for the average, A-weighted sound pressure level at pass-bys for each train category (for a pass-by velocity of von v = 100km/h).

Tab. 6-1 Number of the measured trains and acoutic effect of the STRAILastic_A_inox elements for each train category for velocities ≥100km/h

Train category	No. of measured trains		average, for 100km/h
	reference meas. Mesure	STRAILastic_A_inox	M1 (7.5m/1.2m above rail
RZ-mix	20	24	2.1
Passenger (smooth)	142	174	2.4
Passenger (rough)	221	191	2.7
Total	383	389	2.4

Additionally to the evaluated velocity ranges, all usable pass-bys of all categories and velocity ranges were as well considered for the evaluation.

These results confirm that the STRAILastic_A_inox elements have a significantly bigger effect in the velocity range of ≥100km/h. For the whole velocity range, an average gain reduction of 2.3 dB(A) could be achieved for the passenger train category (rough wheels) as well as a gain reduction of 2.1 dB for the passenger train category (smooth wheels).

In the freight train category, gain reductions of 1.9 dB were measured and in the RZ-mix category, gain reductions of 1.8 dB(A) could be observed.

It must be noted that the track in the measurement section has an extremely good Track Decay Rate. Since the effect of the product STRAILastic_A_inox is based on increasing the TDR and thus, on improving the emitting properties of the rail, it is supposed that (due to the high TDR of the track) the potential for reducing vibrations was minimised and that the effect of the damping elements is even bigger on a track with a lower TDR.

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7 LITERATURE & DOCUMENTS

[1] TSI-CR-NOISE: Entscheidung der Kommission vom 23. 12. 2005 über die Technische Spezifikation für die Interoperabilität (TSI) zum Teilsystem „Fahrzeuge – Lärm“ des konventionellen transeuropäischen Bahnsystems. (Com 2006/66/EG)

[2] EN ISO 3095:2005 "Railway Applications - Acoustics - Measurement of noise emitted by railbound vehicles", edited 2005-11-01

[3] prEN ISO 3095:2010 "Railway Applications - Acoustics - Measurement of noise emitted by railbound vehicles", edited 2010-03-29

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