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Changing the superstructure to minimise noise and vibrations from railway

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Sound and vibrations change, if rail pads are changed. In order to investigate which rail pad has the best performance with respect to environmental noise and vibrations, a measurement campaign encompassing five different rail pads has been carried out along a 400 metres test section of the main railway line at Holmstrup on Fyn. During the campaign sound was recorded by a sound level meter and a pentangular array, and the vibrations were monitored by several accelerometers and force sensors. This paper gives the main findings and shows the impact of the environment during a train pass-by. Total sound level as well as frequency content has been investigated.

1 Introduction

Banedanmark has experienced that the sound pressure level and the sound character (sound quality) changes, when different types of rail pads with respect to dynamic stiffness are used. Softer rail pads protect ballast against acceleratd degradation, but results in more sound emission. In order to investigate the nature and magnitude of changes of sound and vibration levels and frequency spectra due to change of pads, a measurement campaign has been carried out. During the campaign the sound power level, the vertical and horizontal vibrations in the rail, the sleeper, the ballast and the soil and the tonal components have been measured and recorded for subsequent analyses and studies.

The measurements should investigate which type of rail pads could

1) minimise the sound emission

2) avoid any dominating 1/3 octave bands sound levels

3) protect ballast against degradation due to transmission of vibration

4) reduce transmission of vibrations to the environment

2 Basic information

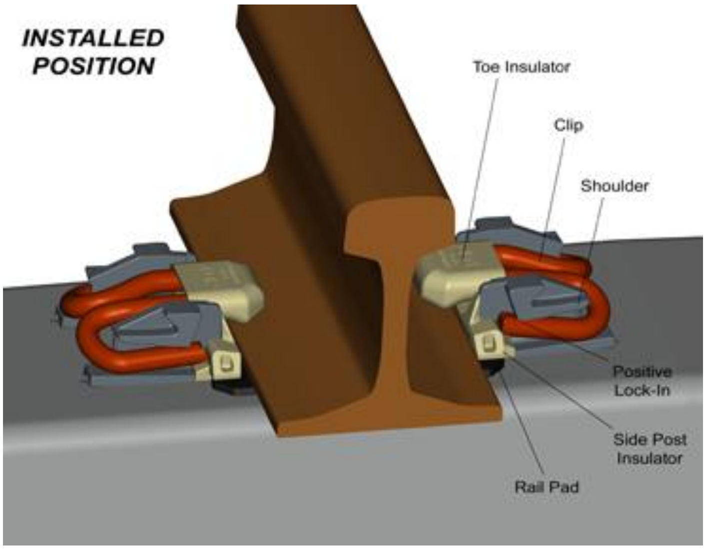
Track property	**Value**
Maximum speed:	160 km/h
The gradient	0,625 %o.
Track type	Dmp: rail type UIC60, monobloc concrete sleepers (2004), Pandrol fast clip fasteners Pandrol 6530 rail pads

3 Methods used

For each type of tested rail pads, the sound and the vibrations have been recorded for each train passage of the measurement position. Several types of measuring technologies have been used in order to get a full picture of sound and vibrations caused by the dynamic interaction between the wheels and rails.

Prior to the noise campaign the site was visit in order to experience the audible sound from train pass-by and afterward. It was found that sound radiated from the rail (singing rail) was most audible after the train pass-by and when the train was still at the test section (up to 300 metres after the measurement position).
Vibrations was measured by B&K 4513 accelerometers positioned on the rails, the sleeper, ballast and the soil adjacent to the ballast, while rail force was measured by Kistler HBM 9241C type piezoelectric force sensors. At each measurement position all signals was recorded by a local placed logger connected to a central PC by a local LAN connection. The logger was started manual as soon as the train was approaching the test section and the recording was continued after the end of the train has passed the measurement position.

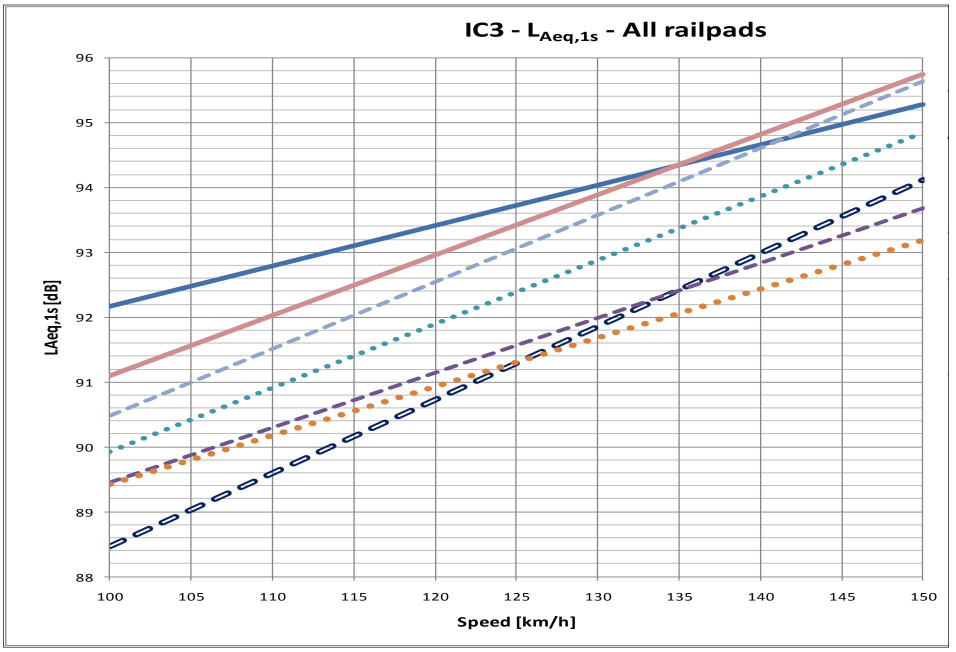
The beam forming measurements were carried out with a 3.2 m diameter pentangular array with 30 B&K type 4959 microphones. The distance between the array and the nearest rail was 3 m and the centre of the array was 1.1 m above the top of the rail.
All rail pads fit into the Pandrol clip system, but the thickness of the pads vary as shown. This is not considered to influence on the force of the clip that holds the rail to the sleeper. The same clips were reused based on confirmation by the producer that the force will remain unchanged.



Day	IC3/IR4 measured	Siemens Desiro measured	IC4 measured	Other
Total	77	23	19	78

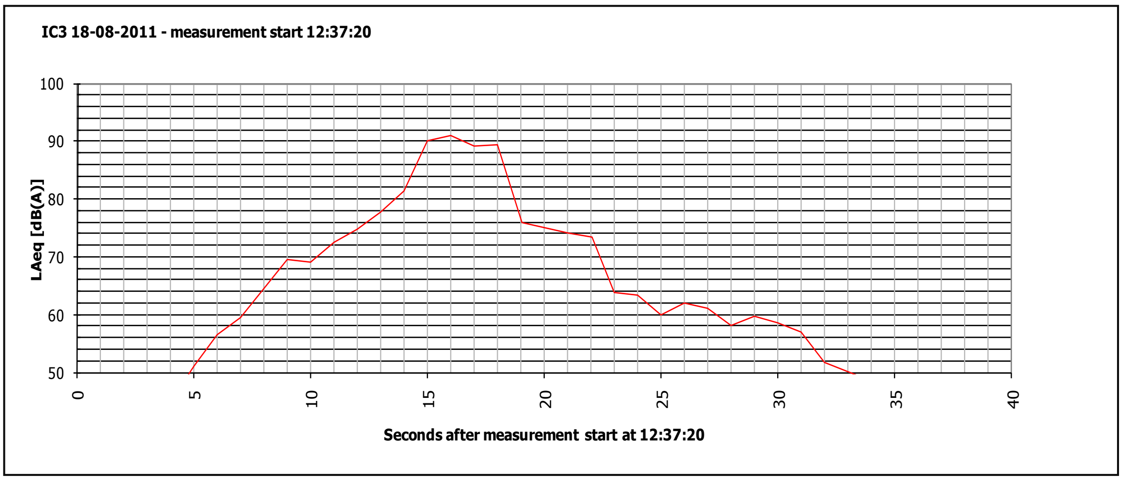
The logged data for each measurement day and each train pass-by has been used. The peak of each one second recording was logged and used in the analyses. This peak has been chosen for every train passage and is considered to be a representative comparable value for the train pass-by noise.

The peak value has been plotted as a function of the train speed (the speed has been estimated from the vibration and force sensors and checked against the speed recording in the array setup with photo sensors). For all train types a trend line (by linear regression) for each type of rail pad has been estimated. The trend lines related to the train type IC3 for each type of rail pad are shown in the figure below.

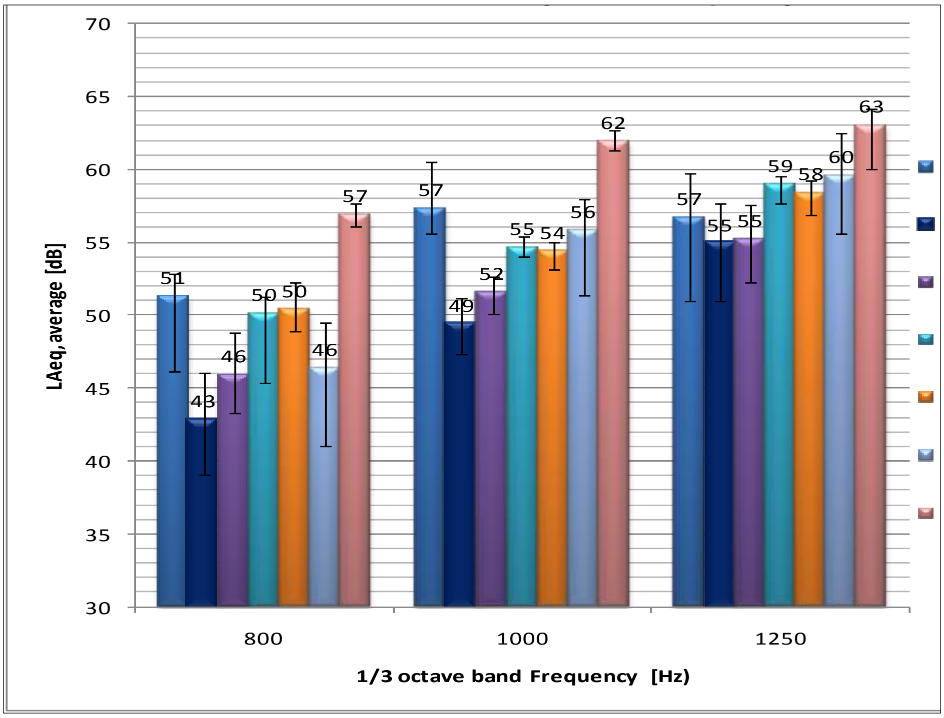


The figure shows a difference between the lowest and the highest value of $L_{Aeq,1s}$ at 120 km/h of approximately 3 dB. At higher speeds this difference declines to 2.5 dB. This finding confirms the expected differences from literature giving figures of 2-3 dB when changing from soft to harder pads.

The time logged recording below shows the typical appearance of the dominating 1/3 octave band sound of 1250 Hz from an IC3 pass-by. The "tail" of the sound level shows a long-lasting sound at 58-62 dB, starting approximately 8 seconds after the train-pass-by and lasting approximately 12-15 seconds. With a train speed for an IC3 train of 33 m/s, the train is about 250m away from the microphone position. Siemens Desiro trains have a "tail" of the sound level a bit earlier as the speed is lower, about 200m away from the microphone position due to a train speed at 23 m/s.



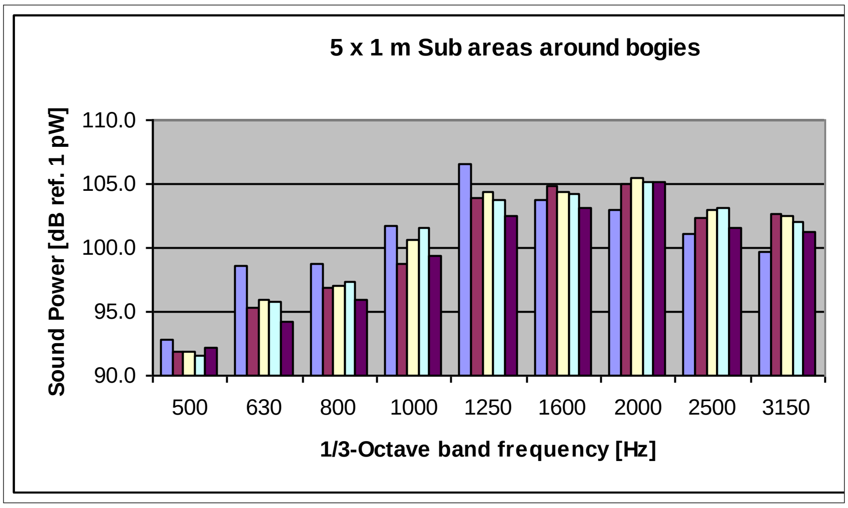
Time logged spectrum at 1250Hz for an IC3 train. With a train speed at 33 m/s the train is 250m away at approximately 12:37:45 (25 seconds after measurement start).



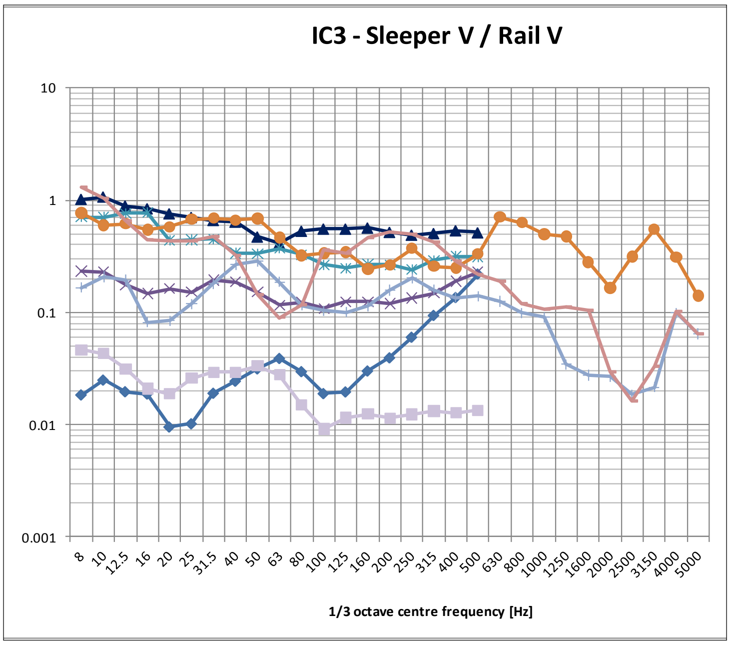
Average L_{Aeq} (only sound from rail) at 1/3 octave bands 800 Hz, 1000 Hz and 1250 Hz 300m after pass-by of IC3 trains,.

The plot for the IC3 trains shows at frequency band 1250 Hz the disparity of the different types of rail pads is smaller than at the frequencies at 800 Hz and 1000 Hz. The measurements also show that when using harder pad types the dominating narrow band sound is 2- 8 dB lower than the baseline pads type with a lower dynamic stiffness. The recorded minimum and maximum values are shown as lines placed on top of the bars in the plots. The average figure is written at top of each bar.

In the following figure one of the plots from the analysis of the pentangular array is shown. The sound power shows some differences compared to the sound level meter recordings. This is properly due to aerodynamic sound underneath the train.



Selected frequency response functions have been analyse as an average of all measured IC3 trains pr. rail pad type. Levels are average levels after speed normalization but no temperature normalization.



Frequency response function (transmission loss) from rail to sleeper in vertical direction for IC3 trains.

The above figure shows that the damping performances of all the tested rail pads are almost constant across the frequency spectra. The response for the harder pads provides almost no damping (transmission loss close to 1). The greatest damping giving the best protection of the ballast against degradation is provided by the softer Baseline pads.