Psychoacoustic study on the acceptance of train passings after rail grinding

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Summary

Maintenance by rail grinding can lead to annoying tonal components for the passing trains shortly after the grinding process. In our contribution for the Internoise 2017 a concept of a psychoacoustic study for noise optimized rail grinding was presented.

The results of the psychoacoustic investigation on the acceptance of train passings with more or less tonal components will be presented in the following. To produce different stimuli with gradually differing tonal components the train passing with strong tonal components were added in different ratios with a train passing without tonal components measured on a reference track. Additionally, various low pass filter were applied on the "tonal train passing". In listening sessions the threshold of acceptance for these stimuli has been detected by using the method of Random Access. The subjective data will be discussed in relation to the spectral modifications and the actual differences in A-weighted level.

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1. Introduction

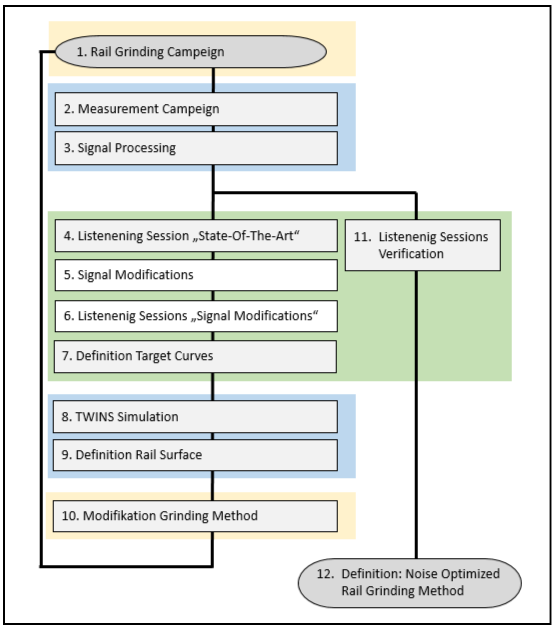

Figure 1. Flow chart of the overall concept of the project "noise optimized rail grinding" as presented in [1]. Yellow: DB Netz, blue: DB Systemtechnik, green: Möhler + Partner Ingenieure AG.

As presented during the Internoise 2017 [1], the DB Netz AG is coordinating the project "Noise Optimized Rail Grinding". Figure 1 shows a flow chart of the whole project, comprehending the participating grinding companies (yellow), DB Systemtechnik (blue) and Möhler + Partner Ingenieure AG (green).

The present paper will concern the approach of the signal modifications (step 5 of the flow chart) and the subjective evaluations (step 6 of the flow chart). In step 4 of the project the annoyance of trains passing in different time intervals after rail grinding was subjectively determined. It appeared that the different rail grinding methods lead to very different annoyances, founded mostly in the dominance of tonal components.

Hence, the focus of step 5 was to modify these strong tonal components stepwise and to determine thus in step 6 the necessary amount of "tonal" reduction to achieve an acceptable sound.

2. Signal modifications

To receive signals with different strengths of tonal components two train passings of the same train on different track sections were selected as initial situation:

- the reference measurement on a not grinded section ("reference") and
- the measurement on a grinded section producing a maximum of tonal component ("grinded")

By mixing these two signals and varying the level relationships, signals were produced with different content of the tonal component of the "grind" signal. Figure 2 shows in a schematic way this approach of the signal combination.

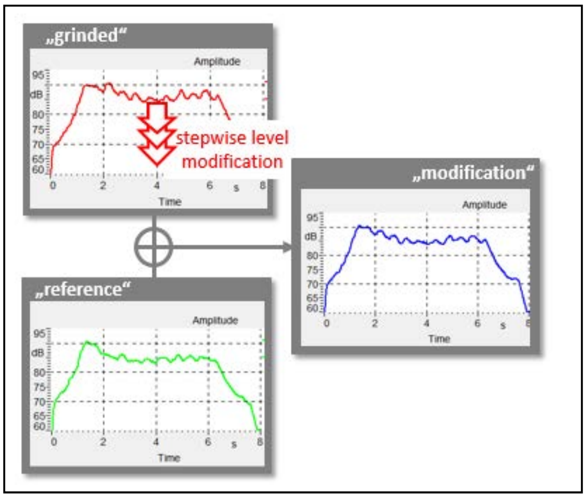

Figure 2. Approach for the signal modification to achieve stimuli with different content of tonal components.

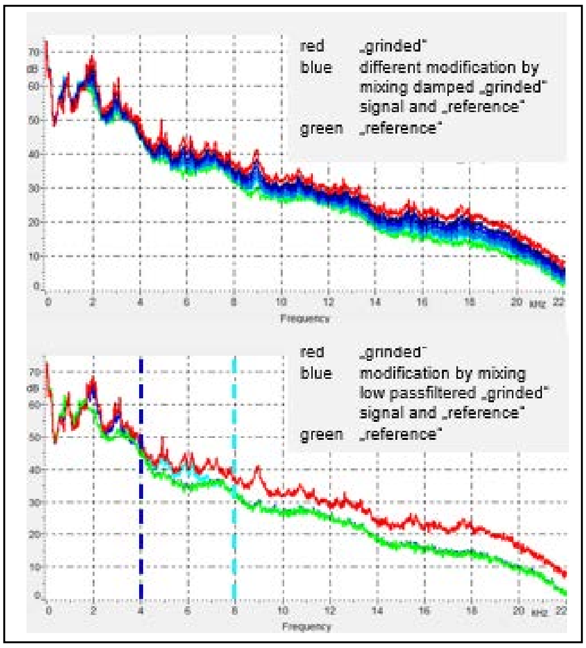

Figure 3. Spectra of the resulting stimuli.

Additionally to the signal mix with level modifications of the "grinded" signal, the "grinded" signal was also low pass filtered at 4 kHz and 8 kHz to obtain also modifications with different spectral content of the overall tonal components.
The spectra of the train passing for all resulting stimuli can be seen in figure 3.

3. Listening sessions: stimuli and psychometric method

In the following, listening sessions were designed to determine the perceived annoyance and the acceptance of the different realized modification.
For four different grinding companies and for three different kind of trains passing (Intercity with a speed of 200 km/h, local train "ET 440" with a speed of 140 km/h and local train "DoSto" with a speed of 120 km/h) single experiments were realized respectively.

To interrogate the annoyance and the acceptance of the stimuli the psychometric method of Random Access with a threshold determination was chosen. Therefore, the subjects had to rank the signals of one grinding section / train passing combination consisting of the following signals regarding to their annoyance:

- "reference"
- "reference" + "grinded" mod LP 4 kHz
- "reference" + "grinded" mod LP 8 kHz
- "reference" + "grinded" mod level #1
- "reference" + "grinded" mod level #2
- "reference" + "grinded" mod level #3
- "reference" + "grinded" mod level #4
- "reference" + "grinded" mod level #5
- "grinded"

After arranging these signals, the subjects had to put an arrow on that signal, which was no longer acceptable.
The signals were presented to the subjects via Stax SR-307 headphones. 20 subjects took part in the experiments

4. Results: annoyance and acceptance

For each investigated combination of "grinding section / train passing" the evaluated ranks were averaged by medians and the threshold of acceptance was calculated by percentiles. Figure 4 shows the results for the combination “grinding section 1 / train passing ET440”.

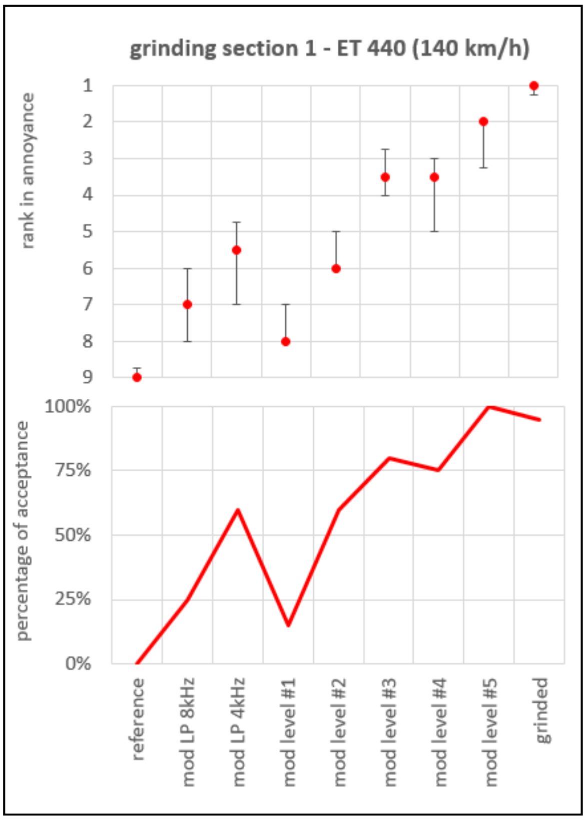

Figure 4. Result of one single experiment (combination “grinding section 1 / train passing ET440”) for the evaluation of 20 subjects

The upper panel shows the rank in annoyance (median and interquartile ranges of 20 subjects) for all evaluated stimuli. Very clear results arise for the original not modified signals “reference” (best rank) and “grinded” (worst rank) whereas all modifications are positioned in between. The modifications with low pass filter achieve even better results than some of the level reduced modifications. If the acceptance is queried (lower panel of figure 4), 50 % of the subjects determine the modification with the 4 kHz low pass filter and all level modifications from #2 on as acceptable.
Figure 5 shows finally the results of all evaluated combinations of grinding section / train passing combinations.
To discuss the different thresholds of acceptance, the 50 % threshold will be compared in the following: Overall, the thresholds of acceptance for the single train passings show a similar trend among each other. The IC seems to be less acceptable than the other investigated trains. So, the 50 % threshold of acceptance for the IC is reached depending on the grinding section between the stimuli “mod level #3” and “mod level #5”, whereas for the “ET440” it is already reached between “mod level #2” and “mod level #4”. Also the spectral decreases from 4 kHz (stimulus “mod LP 4 kHz”) result for the “ET440” in better acceptance rates than 50 %. Same for the “DoSto”: except for grinding section 1, a diminution of the tonal components above 4 kHz (stimuli “mod LP 4 kHz”) produce an improvement in annoyance and acceptance. The level reductions of the “DoSto” are perceived of 50 % of the subjects as acceptable starting with the stimulus “level mod #4”.
The different acceptance thresholds of the different trains and the grinding sections can be explained by considering the spectra of the stimuli (figure 6). The IC produces the highest levels, so the biggest reduction is necessary to reach a reasonable acceptance rate, the diminution of the frequency range above 8 resp. 4 kHz is not that sufficient as for the other trains as the number of tonal components is even less than for the other trains.
The ET440 however produces the most tonal components on the grinded tracks, so a reduction of the frequencies above 4 kHz is very effective. However, the diminution above 8 kHz being not that sufficient underlines the importance of the frequency range between 4 and 8 kHz.
Also the “DoSto” train shows prominent tonal components on the grinded sections which is again in line with the evaluation of the stimuli with low pass filter.

5. Conclusions and Outlook

By involving the psychoacoustics into the consideration of rail noise an effective improvement of disturbing noise for the residents can be pursued.

In the present study, tonal components which can occur after maintaining rail grinding have been modified step wise. These signals have been evaluated regarding their annoyance and their acceptance. In cooperation with DB Netz AG and DB Systemtechnik limit curves for maintaining rail grinding will be developed in the further study by combining the detected thresholds of acceptance with the respective frequency spectra.

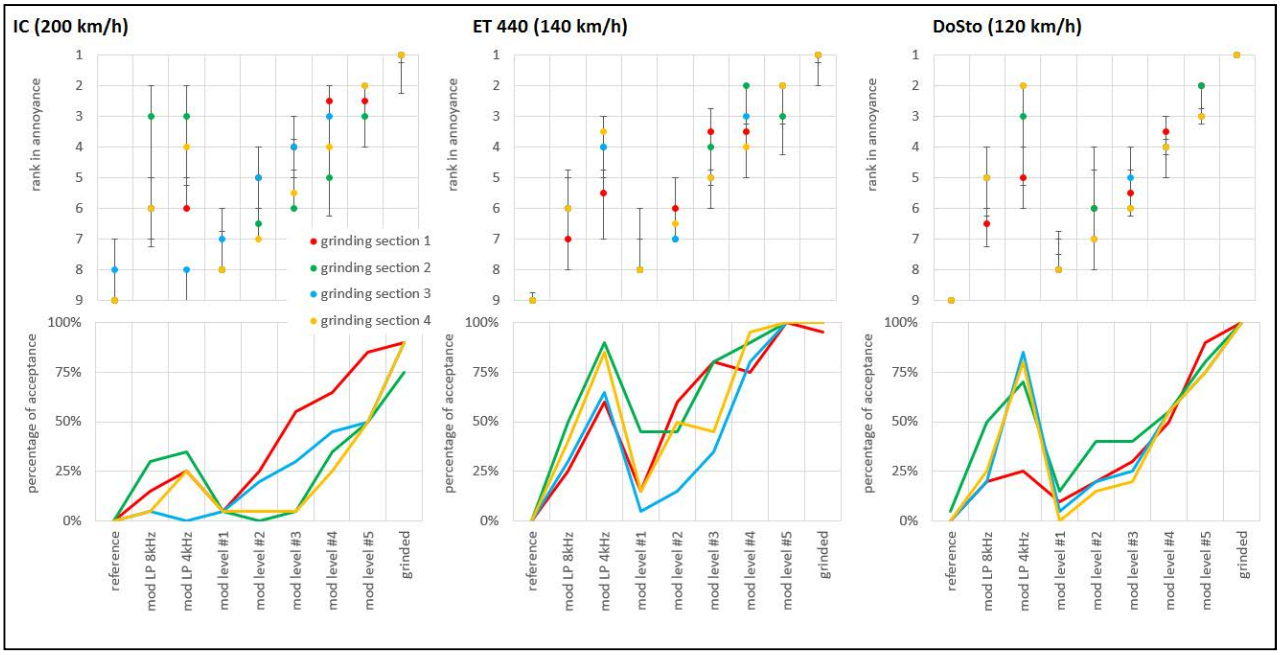

Figure 5. Results of all "grinding section / train passing" combinations.

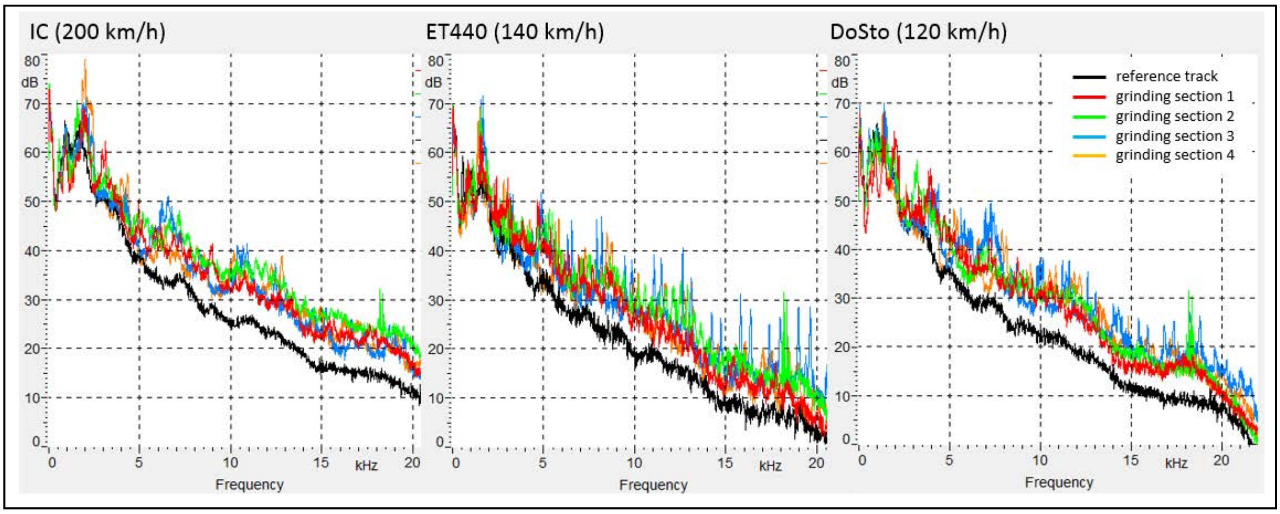

Figure 6. Spectra (averaged over the main train passing) of all original signals (on the 4 different grinding sections and on the reference track).

References

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