ROLLING NOISE REDUCTION BY APPLYING AN ACOUSTICAL GRINDING CRITERION

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Abstract
The relation between rail/wheel roughness and rolling noise of trains has been established in the past decades. By means of a new rail roughness monitoring system and an acoustical criterion for rail grinding, it is possible to determine where rail grinding is an effective measure to reduce rolling noise emission. In this way, periodical grinding could serve as an alternative to fitting noise barriers. The monitoring system (on a measuring coach) is used to build a database with rail roughness spectra of the entire Dutch railway network. These roughness data are coupled to a database with noise emission numbers. By taking account of train intensities, train speeds and typical wheel roughness, an acoustically effective grinding programme can be composed.

1. Introduction

Both rail roughness and wheel roughness play an important role in the generation of railway noise. It has been shown that railway noise can be reduced by decreasing the total roughness of rails and wheels [1]. While the causes of wheel roughness can be related to the kind of braking system of the rolling stock, the generation and growth of rail roughness appears to be a far more complicated matter, as often a transition between smooth and corrugated rails occurs without a clear change of track or vehicle properties [2]. In contrast to this, rail roughness can be reduced effectively (lasting over a year) by grinding, while the effect of reprofiling or truing wheel treads is restricted to only a few weeks or months of service.

Until now, the annual grinding programme of the Dutch Railways Infrastructure Department (NS RIB) is based on track maintenance criteria only (damage control). Grinding as a measure against excessive noise emission is not (yet) accounted for in the Dutch noise legislation, and is therefore not supported by fundings. However, the potential of rail grinding as an alternative to raising noise barriers or reducing train intensity on busy lines has been recognized some years ago by NS RIB, who is appointed by the Ministery of Environmental Affairs to guard the noise emission of railway traffic. In contrast to the German approach, the so called *Besonders überwachtes Gleis*, where a 3 dB(A) emission bonus is granted for regularly ground lines with less than 80% cargo service, the method presented here will fully account for the varying wheel roughness of different rolling stock.

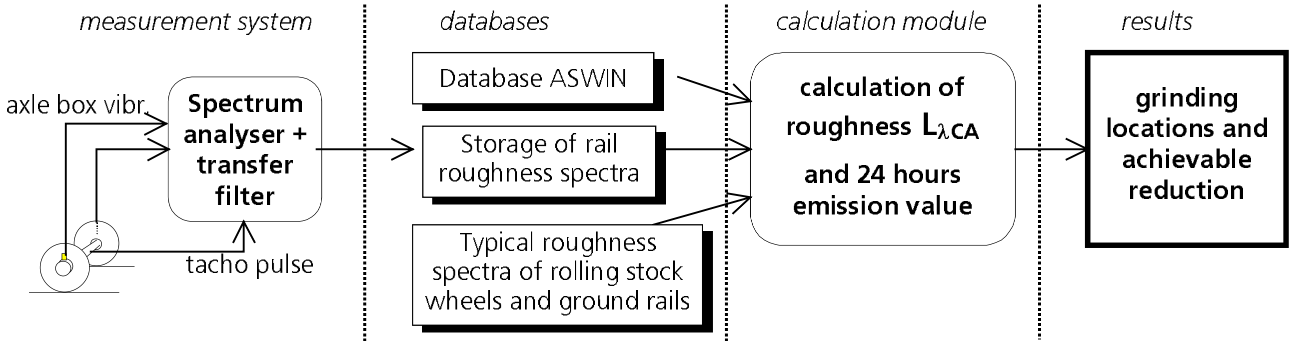
The research described in this paper is a pilot study comprising of the design and implementation of a rail roughness measurement system, an adjustment of the EURANO programme (a GIS tool for railway noise scenario studies), and finally an evaluation of roughness data and the emission reductions that can be achieved.

2. Measurement of rail roughness

The rail roughness is measured in a measuring coach using the axle-box accelerometer signals of an unbraked wheelset. The signals are spectrally analysed in third octave wavelength bands. The conversion from vibration levels to roughness levels is done in a speed-dependent filterbank. These transfer filters are calibrated by comparing the system's output to an accurate hand-held rail roughness instrument. The measurement system, called MSAR, has an overall accuracy of about 2 dB.

Resolution

The MSAR stores two rail roughness spectra (left and right rail) per 10 meter of track. The actual resolution of the system, however, is much less due to two causes. During the calibration runs it was noticed that if the roughness of the left and right rail differs extremely, both axle-boxes vibrate proportional to the roughest rail. Due to this cross-talk effect it is adequate to store only the energetically averaged spectrum of both signals. Furthermore, the vibration signals contain many spikes originating from wheel flanges that touch the side of the rail, and from joints. Also, the lateral position of the running wheelset is generally not the same when running the same track twice. The roughness of a different running surface is then measured, leading to different results from individual runs on the same track. After evaluating several longitudinal averaging methods, it



turned out that taking the median value per 10 succesive sections of 10 m yields the best correlation between the results of different runs. This way, a rail roughness spectrum is rendered per 100 m of track.

Measurement campaign

The total length of the Dutch railway network is about 4700 km of track (including parallel tracks). The condition of the superstructure of the network is monitored twice a year in a 20 days' measurement campaign. The results presented here have been measured in the campaign of October 1999.

3. Noise emission calculations

Rail en wheel roughness is not incorporated in the emission formula of the national Reken- en Meetvoorschrift Railverkeerslawaai [3] (comparable to German *16.BImSchV*). For the present pilot study, a measure for roughness is developed that is proportional to the dB(A). This measure, the $L_{\lambda CA}$, is a weighted spectral sum like the L_{Aeq} and is dependent on train speed. It includes the influence of force excitation, contact filter and A-weighting [4]. The emission is then corrected by first subtracting the reference roughness which is considered representative for the measurements on which [3] is based, and next adding the actual rail roughness and typical wheel roughness (depending on the braking system) to the emission.

This calculation scheme is added as an extension to EURANO, a GIS-programme used by NS, DB, SNCF and SBB for railway noise calculations [5].

Now, the ASWIN database (containing all track, vehicle and traffic parameters relevant for noise calculations) is used to calculate the noise emission corrected for rail roughness. Also, the noise emission remaining after grinding the tracks is computed. The difference between these datasets is the achievable noise reduction. A list or map can be shown with track sections where grinding will be most effective. The effectiveness is here expressed as a certain acoustical grinding criterion, e.g. 'grind those pieces of track where a noise emission reduction of over 5 dB(A) can be achieved'. If it is aimed to reduce the noise emission of a certain specified railway line or the entire network, the reduction of the average emission of that line or network can be computed as well.

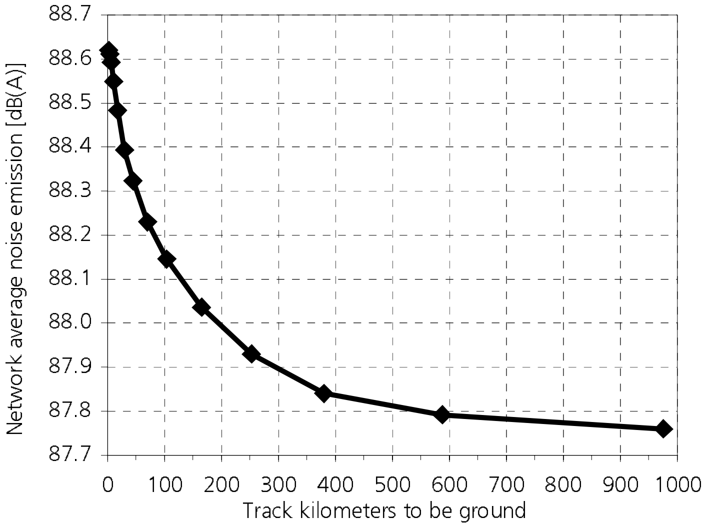
Results

If the acoustical grinding criterion is set to 7 dB(A), the network's average emission will decrease by 0.5 dB(A). From the graph it can be read that 104 km of track need to be ground (2 % of the total network). For a single line with many corrugated sites, the reduction of the average will be between 0.5 dB and 7 dB.

The effectiveness of grinding, with respect to noise reduction, decreases rapidly with grinding length, as shown in the graph. For an average reduction of 0.9 dB, 1000 km should be ground.

Discussion

The acoustical grinding criterion offers several possiblities to reduce railway noise. How the criterion should be assessed and applied, depends on one's goals. Apart from



the methods mentioned above, also noise emission bottlenecks can be traced on a line where the actual emission has exceeded or will exceed a certain threshold. A combination of low barriers and grinding may also be attractive if high barriers are undesirable. From the viewpoint of perception, it may be more appropriate to calculate the reduction of noise immision or annoyance, as the benefits of grinding in urban areas will be higher than in rural areas.

If older types of rolling stock with cast-iron brakes are replaced by newer disc-braked trains, railway traffic will become less noisier. In that case, rail roughness will dominate the total roughness of rail and wheels more and more. It is calculated that grinding will then double its influence on the emission, which will make it an interesting measure to further reduce railway noise.

[1] P. Dings and M. Dittrich, "Roughness on Dutch Railway Wheels and Rails", *Journal of Sound and Vibration* **193** (1), pp. 103-112 (1996).

[2] P. Dings *et al.*, "Silent Track Data Gathered in the Netherlands", Silent Track Technical Document (1999).

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[4] Stijn van Lier, 'The measurement, analysis, and presentation of wheel and rail roughness', NSTO/97/9571011/005 (1997).

[5] Frank Elbers, 'Methods and tools for monitoring and prediction of the environmental impact of railway noise', 6th International Workshop on Railway Noise, Ile des Embiez (1998).