Monitoring system for track roughness

Martin Höjer
Acoustic department, Tyréns AB, Stockholm, Sweden.

Martin Almgren
Noise specialist, Stockholms Läns Landsting, Trafikförvaltningen, Stockholm, Sweden.

Summary

As a part of the EU-financed project "Quiet track", a method for monitoring of track parameters influencing the exterior noise, is developed in the Stockholm Metro. By continuous monitoring of the sound level beneath a regular operational train of model C20, the aim is to facilitate determination of rail roughness and track decay rate (TDR). The objective is that the monitoring will provide more efficient track maintenance, possibility to optimize track maintenance to reduce rolling noise, and increase the knowledge of the rail status in terms of noise generation, which may facilitate increased accuracy in measured and calculated noise levels. This paper, give a closer description of the advantages with the system, the targets of the project, basic principles for the measurement system and some preliminary measurement results.

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1. Introduction

The objective with the work described in this paper is to develop a monitoring system for track roughness to be used as a maintenance tool. The system should be able to grade the track roughness in a scale of e.g. 1-5 for every 20 meters of rail. The results can be presented graphically on a map or as tabular data in combination with track coordinates.

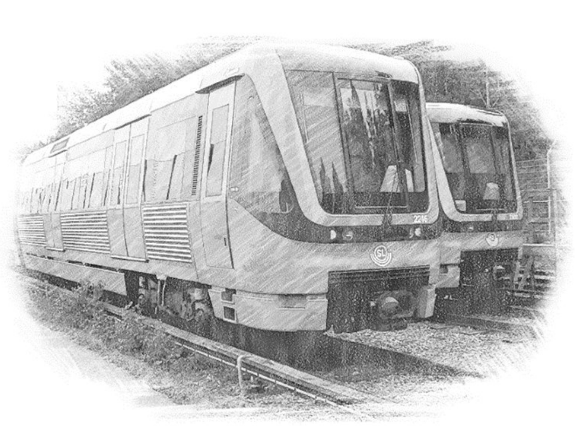

Figure 1. C20 vehicle used for testing of the monitoring system in Stockholm.

The monitoring system has been mounted on one ordinary C20 vehicle that is used in the daily traffic. The vehicle has been prepared only in the meaning of extra knowledge about the wheel roughness for the wheels running close to the mounted microphones. Even though the objective is to grade the roughness in a scale of e.g. 1-5 comparison with direct measurements of track roughness has been performed in order to increase the accuracy of the method and to validate the model.

2. Literature study

The work refers to an initial study of the available research regarding monitoring of track roughness. The goal with the study is to determine the best available types of transducers and the optimal transducer position in order to monitor track roughness using an ordinary vehicle used in daily traffic. The aim of the literature study is to:

- Determine the best type of measurement system for monitoring of the track roughness
- Theoretical study of the limitations for different measurement techniques
- Study the influence from roughness on the exterior pass by noise levels.
- Investigate what roughness resolution is needed in order to predict accurate exterior noise levels for common track types.

2.1. MONITORING SYSTEMS FOR TRACK ROUGHNESS

Since the middle of 1980s, several systems have been used to measure the surface roughness of the railhead. Some systems are commercially available while other systems can be considered as development/test equipment. Several monitoring systems have been identified in the literature [3], [6]-[11]. The measurement methods can be divided into direct and indirect methods according to Figure 3 below.

2.1.1. Direct method

The rail surface is scanned directly. The most frequently used systems apply displacement transducers or accelerometers in sensors that touch the rail.
There exist two distinct groups of measurement system for direct measurements, fixed-length systems and trolley systems.
The fixed-length system is normally around 1.2 meter or shorter. During the measurements, the measurement device is fixed on the rail and the integrated moving measurement device measures the rail profile. The measurement device is moved to a new measurement segment of the rail. Example of measurement systems based on 1.2 meter beams is the RM 1200E by Muller-BBM and the ØDS TRM02 system.
The trolley systems are hand operated systems that roll on the rail while measuring the rail roughness. Example of the trolley systems are Corrugation Analysis Trolley (CAT) (reference [10]) and AEA Technology Rail trolley. (DeltaRail trolley), (reference [11]).

2.1.2. Indirect method

Several indirect measurement methods are described in the literature. Usually the methods rely on accelerometer measurements on the axel-box or noise under the measurement coach but one method that was investigated used an interferometer. All the studied indirect methods are train/coach mounted systems.
The methods that have been studied used systems that was installed on the train.

- HSRCA (reference [7])
- SMW (reference [8],[9])
- ARRoW (reference [6])
- Interferrometer (reference [3])

2.1.3. Limitations of measurement methods

Fixed length methods are slow but precise. They cannot measure long wavelengths.
Trolley methods are faster than fixed length but still rather slow. The precision is reduced, compared to fixed length methods, but the method is capable of measuring longer wavelengths.
Axle-box accelerometer methods are limited in wavelength by the contact filter. The transfer function between the contact point between wheel-rail and the accelerometer needs to be known. The transfer function can be estimated with measurements. Other vibrations can disturb the measurement. The axle-box method is less accurate than the direct methods but the method is much faster than the direct methods.
Under coach noise methods are sensitive to other acoustic disturbances like wind and installations. The accuracy are less than for the direct methods but the method is much faster than the direct methods.

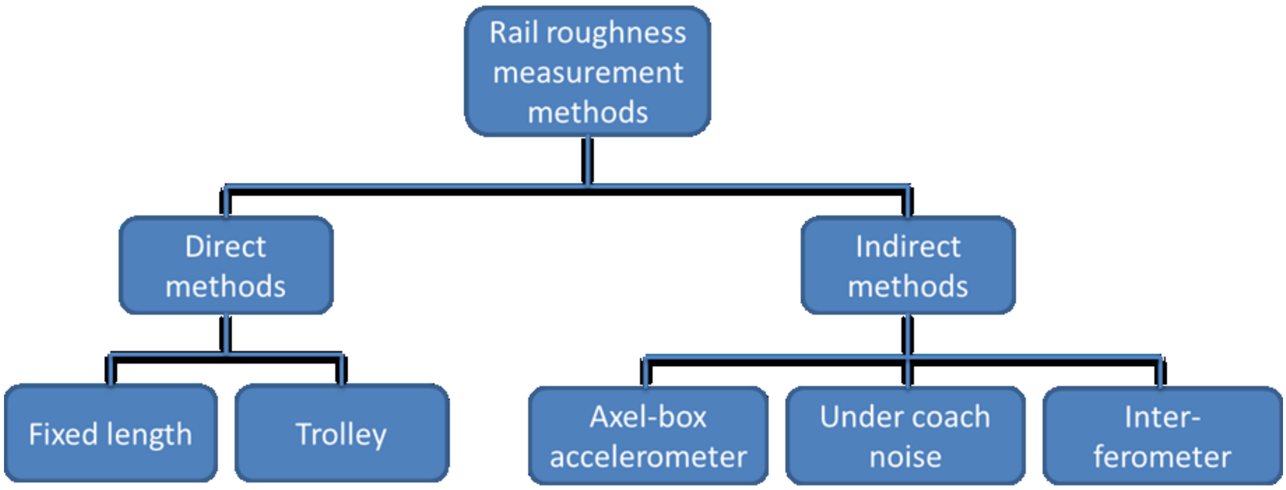

Figure 2. Overview – Methods for monitoring of rail roughness

3. Description of monitoring system

Based on the knowledge of how the noise is generated from wheel/rail irregularities to noise transmitted from (in the present case) mainly the track, a measurement system has been built. The measurement system uses measured noise close to the wheel/rail contact to calculate the rail roughness. The monitoring system has been installed on a C20 vehicle used on the green line in the Stockholm subway.

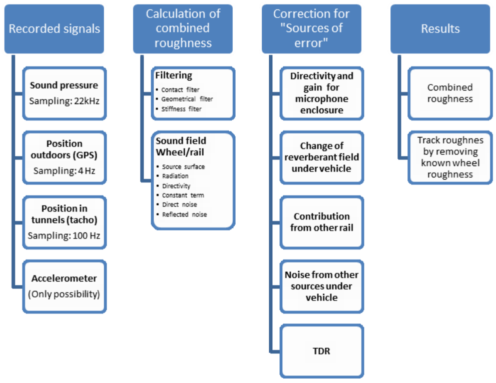

Figure 3. Principal concept for monitoring of track roughness from sound pressure.

A model, resulting in a transfer function between measured sound pressure and track roughness, has been developed. The model take into account contributions from parameters such as:

- Track decay rate (estimated)
- Known wheel roughness
- Wheel/rail contact filter
- Directivity for noise from the rail
- Direct noise
- Reflected noise

The following sources of error have been studied in order to minimize the error in the predicted track roughness:

- Reflections under the vehicle
- Noise contribution from the second wheel/rail contact.
- Noise from other sources under the vehicle
- Turbulent noise around the microphone
- Microphone enclosure directivity

3.1. Monitoring hardware

The monitoring system consists of four microphones installed underneath the train, one accelerometer mounted on the B-boggi and one tachometer. Inside the train the measurement signals are collected with two USB-measuring systems. The measuring systems are connected to a portable computer that analyses the measurement and provides communication to land. A GPS-receiver facilitating positioning of the train and a 4G-antenna which provide communication with the system without being on the train, are connected to the computer. In the tunnels speed and position are given by a tachometer transducer mounted on the wheel axel.

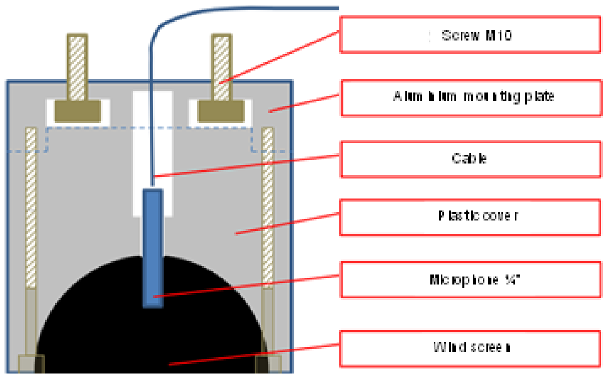

Figure 4. Principal construction of microphone enclosure.

4. Direct measurements

In order to verify the predicted/monitored track roughness, direct measurements has been carried out using a rail surface analyser (RSA) from APT.

4.1. Wheel roughness measurements

Since the method described in this paper measure the combined roughness for wheel and rail it is necessary to know the wheel roughness in order to be able to extract the roughness for the track. About one month after machining of all wheels on the boogie in a lathe the wheel roughness was measured. In general all roughness levels are low but on some wheels the roughness varies between the three tracks which means that there are some kind of wear. A typical result is showed in Figure 5 below.

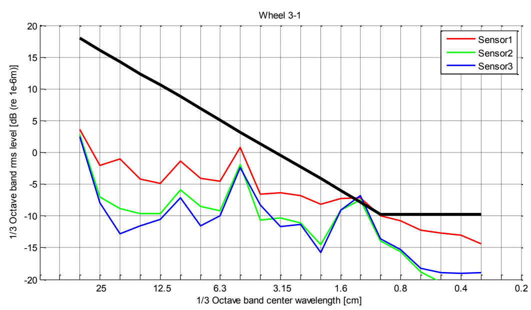

Figure 5. Typical wheel roughness for wheel close to the monitoring system.

Figure 7. Measurement of track roughness using a rail surface analyser (RSA) from APT.

4.2. Track roughness measurements

Rail roughness has been measured (direct method) in order to compare with the indirect measured (monitored) roughness. One test site with straight track and possibility for the train to keep constant speed has been measured. The test site is located between Högdalen and Bandhagen. The measurements were carried out during night time in both directions of the track. The displacement was measured in three parallel tracks with 1cm spacing. The average of the three parallel measurements has been compared to monitored track roughness.

5. Validation - Högdalen-Bandhagen

In Figure 8 the monitored combined wheel/rail roughness is plotted against the combined wheel/rail roughness from the direct measurements on the same track section. The roughness levels are in general rather low. From the results presented in Figure 8 it can be seen that the monitored roughness is higher compared to the direct measurements of combined wheel/rail roughness. Especially the measurements performed on the “South track – section 2” and the “North track – section 1” differ from the direct measurements. The speed (65km/h) is constant over the whole section. The reason for the deviations will be further investigated during the second half of the Quiet Track project. The over predicted roughness levels at low frequencies (long wavelength) can probably be adjusted for in the calculation model between noise and roughness. An alternative way is to use the data coming from the accelerometer since these low frequencies are below the limitation due to the contact filter. At high frequencies the contribution from wheel resonances might be the cause for over predicting the roughness. Since the monitoring system will be installed on the same vehicle during the whole project, these tonal components can be determined and removed during the project. In general, the initial results indicate that the objective with this monitoring system can be fulfilled.

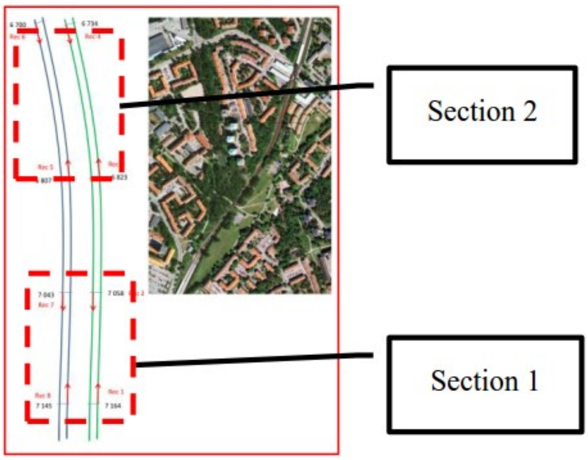

Figure 6. Test site overview

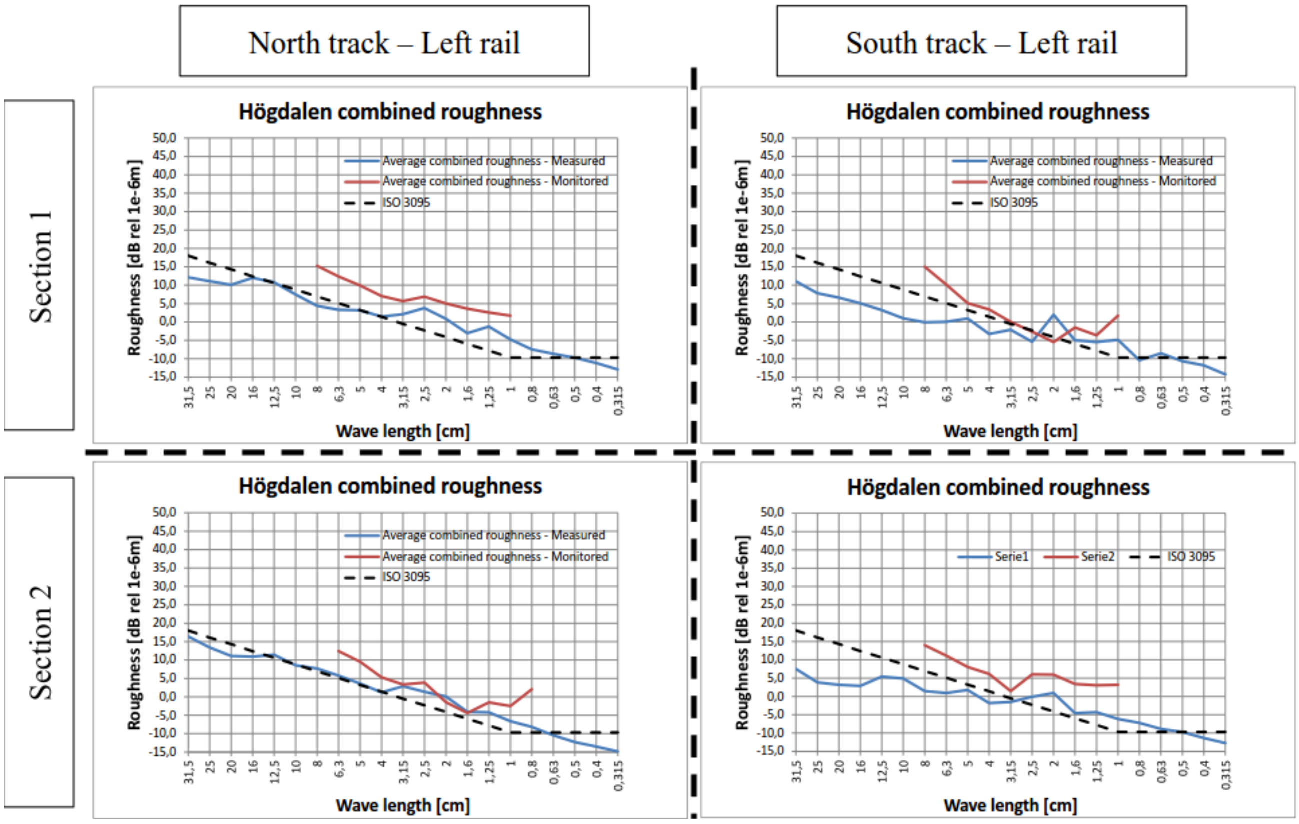

Figure 8. Comparison between monitored roughness and direct measurements of the combined track and wheel roughness.

6. Discussion & Future work

In the second part of the project further improvement of the monitoring system will be carried out. More direct measurements of track roughness will be carried out in order to further calibrate the prediction of the monitored roughness. The accuracy of the monitored roughness will be validated and limitations with the used method will be described in the next deliverable. Presentation of the data will be done in a way so that it can easily be used by the infra-structure manager in order to optimize maintenance of the track.
Deviations, due to different surrounding obstacles (tunnel walls, platforms, noise barriers), will be studied during the project.

Acknowledgement

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