A road test on acoustic wheel roughness measurement
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ABSTRACT
Within the preparation of the upcoming revision of the European acoustic roughness measurement standard for railway applications, EN 15610 (1), some members of CEN TC 256 WG 3 “Acoustics” carried out a joint measurement exercise. This gave evidence, that all participants had the same idea of the measurement task and the procedure to collect an appropriate set of measurement data.

Six different sets of data, defined by the combination of a measurement kit and an operator were collected. Each set consists of a selection of traces in the center area of the running band of the wheel. All data have been analyzed with the software associated with the measurement device and additionally all with the same software. The exercise demonstrated, that all measurement kits produce sufficient data.

The presentation gives detailed results on influences from surface preparation, operators, measurement devices and software.

Keywords: Railbound vehicles; Data acquisition systems, recorders and data storage devices; Measurements of other quantities

1. INTRODUCTION
Acoustic roughness is that kind of surface roughness which excites railway rolling noise when railway vehicles move. The wavelength range of interest depends on the operational speed. The complete range of wavelengths of interest comprises the 1/3-octave wavelengths from 3mm up to 1000mm and has amplitudes in the range of 1µm. For acoustic type test of vehicles the acoustic roughness of the test track is limited to ensure a measurement result of sound levels not dominated by the track quality. The acoustic roughness limit is set to less than 0.3µm for short wavelength. This means, the amplitudes are tiny, compared to their associated wavelength.

Measurements of surface roughness within the requested range of precision are handled under lab conditions reliably, but their application in field tests is still an ambitious task. Engineers designing instruments for measurements on railway wheels and rails must develop a proper arrangement of measurement specimen and sensors to ensure measurements of appropriate precision.

For acoustic roughness of rails the sensor needs to be moved along the rail, for wheel roughness measurements the test specimen needs to be rotated to enable a measurement of the whole circumference of wheels.

Until now there are no standards for a calibration of acoustic roughness measurement equipment for railway application, though this kind of measurement is performed to validate running surfaces, to be in line with requirements set out in standards used in homologation and conformity assessment tasks.

The standardization group CEN TC 256 WG 3 has carried out a field test in 2009 to check, whether the standard EN 15610 offers a procedure to obtain reproducible and trustworthy data of acoustic track roughness.

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roughness (4). A report on this test was published as technical report CEN/TR 15874 (3). This report offered the best available information on track roughness measurement precision obtained from measurement with the most common measurement devices.

The European acoustic roughness measurement standard EN 15610 is revised by the CEN TC 256, WG3 "Acoustics". The new issue shall benefit from the experiences collected since the publication of the first issue and will have an enlarged scope, as measurement of wheel running surfaces will be included.

2. PURPOSE OF THE ROAD TEST

There is no standardized calibration procedure for acoustic roughness measurement devices for railway applications. Studies on the comparability of different wheel roughness measurement devices are very few (4). For this reason WG3 organized a common measurement exercise. The application of the drafted measurement procedure, which was based mainly on outcome of the European Acoutrain project (5) was intended to be checked for robustness and the measurement results should be checked for any influences of the measurement execution, the measurement kit or the persons carrying out measurement and analysis of data.

3. THE MEASUREMENT EXERCISE

The measurement exercise was performed in 2014 at Sept 30 and Oct 01 as a meeting of all participants with common access to the test specimen.

3.1 Test specimen

A powered two axle bogie of an electrical multiple unit was provided as test specimen. The disc braked wheelsets have a nominal diameter of 850mm and are designed for operation up to 160km/h in regional traffic. The bogie had been in service before the test and had been removed from the vehicle during repairs. The wheelsets were in operational conditions though some corrugation had appeared.

![Figure 1 – The bogie used in the test.](image1.png)

![Figure 2 – The cleaned running surfaces of wheelset no. 1.](image2.png)
The bogie had been lifted off the track and was supported by wooden blocks at its axle boxes. The bogie was placed above a pit; the lateral position in relation to the track was approximately similar to the standard conditions in operation.

The wheels were in typical extended service condition, with pits, small flats, contamination, hollow wear, marks from standing and some rolling contact fatigue flanking in Zone 1 (field side). They were also rusty at the beginning of the exercise.

The running band was not obvious when the wheels were rusty. It became more visually apparent when rust and contamination was removed.

3.2 Test instruction

The test specification required, that a set of measurements should be carried out with 5mm transverse spacing on all four wheels of the bogie. The tread datum, 70mm from flange back, was always included. For the single probe instruments the traces to be measured were reduced to a 10mm transverse spacing scheme. Initially, tests were carried out by three of the teams on wheels as-found, including rust and contamination. Subsequently the wheels were cleaned with a soft wire brush and brake cleaning fluid. All measurement teams then measured on all four cleaned wheels.

3.3 Measurements

Four different measurement kits were used. Instruments were equipped with a single or three sensors. One kit provided synchronously operating sensors for both wheels of the wheelset to be measured. Two instruments were equipped with a magnetic trigger to detect the completion of a revolution, the others calculate correlations within the data to determine data segments associated with a completed revolution of the wheel under measurement.

One type of instrument was used by three participants, the other instruments have been used by one participant each.

All teams were able to carry out the tests efficiently without any major problems. Nevertheless, the measurement of 4 wheels using one device, within an ideal workshop environment, typically took between two and three hours. The test specification, especially in terms of the number of lines to be measured, was not always able to be followed exactly for practical reasons.

3.4 Data Analysis

All data was analysed using the procedure supplied in EN 15610:2011. This means there was a removal of non-relevant pits and spikes and a curvature processing, which offers a strategy to eliminate influences of small dips with smaller size than the dimensions of the rail-wheel contact zone.

All data have been analysed using the software associated with the measurement device and additionally all with the same software.

4. RESULTS

The joint measurement exercise gave evidence, that all participants had the same idea of the measurement task and the procedure to collect an appropriate set of measurement data.

The resulting data were checked for influence from various parameters. The results are presented in...
figure 4 up to figure 9. Each of them shows one-third octave spectra of acoustic roughness versus the associated wavelength.

The result of the check of any operators influence at the same serial specimen of the measurement device is presented in figure 4. Two persons have measured the same traces at the same wheel with the same measurement device. There is no systematic influence of the person. Any deviations between two measurements of the same trace are distributed statistically.

Figure 4 – Analysis of device operator and device specimen influence.

Figure 5 – Analysis of measurement repetition influence.
The result of the check of the influence of repetitions of the same measurement is presented in figure 5. As before the results show negligible variations of statistical character with comparable spread of data.

![Figure 5](image1.png)

Figure 6 – Analysis of participants influence using their own devices of the same type.

In figure 6 the comparison of data produced within measurements using different specimen of the same measurement device type by different operators is presented. In figure 7 the same analysis is presented, taking data measured by different measurement device types into account.

![Figure 6](image2.png)

![Figure 7](image3.png)

– Figure 7 – Different participants using different types of measurement devices
The spread of data generated within the test for one-third octave spectra of acoustic roughness averaged from the measurement traces taken into account is presented in figure 8. Obviously the overall spread is very small.

\[\text{Figure 8 – Comparison of spread of results in terms of a single averaged spectrum per participant}\]

As the selection of traces is based on an identification of the running surface, it must be ensured to

\[\text{Figure 9 – Range of results from five traces with a lateral spacing of 5mm}\]

The most important influence is the selection of the measurement trace as shown in figure 9. The influence of a specific measurement kit or the operator performing the measurement is a lot smaller than the influence of the selection of traces to collect data.

As the selection of traces is based on an identification of the running surface, it must be ensured to
have a documented and traceable selection of appropriate traces.

Another important influence on the data was identified in the measurement preparation process. Figure 10 provides results from three different surface condition. As presented in figure 3 the running surfaces were worn and rusty before the measurements started. Though all surfaces have been cleaned there has been a collection of additional data during the cleaning process. Figure 10 shows the result of the 2-step cleaning process:

![Figure 10 – Effect of cleaning the running surface](image)

The brown line provides the measurement result of the running surface as supplied as original state. The pink line is received from data collected after the application of brake cleaning fluid. Both lines show approximately the same result. Cleaning the surface using a soft wire brush removed a lot of particles from the surface. As a result from this cleaning the number of date removed within the EN 15610 pits and spikes correction procedure decreased a lot and the roughness in that wavelength area relevant for speeds of 80km/h up to 160km/h was 2dB lower than before.

5. CONCLUSIONS

The road test demonstrated the used wheel roughness measurement devices to be able to offer appropriate means to perform repeatable and traceable measurements of acoustic wheel roughness. The influence of measurement equipment and its operator is negligible compared to the appropriate choice of traces on the running surface to be measured and a careful cleaning of the surfaces to be measured.

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4876