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TRAIN-"WEIGHT IN MOTION" COMBINED WITH NOISE/VIBRATION EMISSION MONITORING TOWARDS AUTOMATED ACOUSTICAL WHEEL ROUGHNESS ESTIMATION

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ABSTRACT

In 2011, INFRABEL (Belgian-railway-Infra-manager) decided to invest in W.I.M - Weight-In-Motion monitoring systems. Initially the focus of the project was the weighing of freight train wagons, the load distribution on the wagons, and the detection and classification of wheel faults. Soon it was seen that integration of noise emission measurement (L(A)eq,tp), by adding one microphone at 7.5 m from the track centre, and acoustical wheel quality, by adding one vertical accelerometer on the rail, had more than one advantage. The additional cost of the hardware was minor compared with global cost of an installation: track works, power, and ICT-cost, etc... Automatically, data captured by weighing sensors could directly be used as an input for the acoustical wheel roughness calculation modules and finally lead to automated real-time processing and estimation of individual wheel roughness data. Today, after combining the knowledge of SD&M and Schenck Process, such systems are available and software-optimized, after being operational at more than 25 locations in Belgium. It is possible, not only to detect axle loads and wheel flats, but also to calculate the running band wheel roughness, resulting in counting the number of axles equipped with disk brakes, composite (K-LL) or cast-iron brake-blocks running on railway networks.

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1. SYSTEM REQUIREMENTS

Since 2011 until today, systems to measure the wheel profile of running trains exist, but there are by our knowledge no systems that can measure and calculate the acoustical wheel roughness of running trains. Therefore, a request, development and further optimalisation was done.

The initial criteria for the design and delivery of systems that are capable to combine weight in motion with noise and vibration monitoring towards automated acoustical wheel roughness estimation were:

- Axle loads <30 ton /axle
- Data available and processed 30s after the pass-by
- Maximum 2400 axles/hour
- +/- 5% precision of the total train weight
- 10% precision of the axle loads (30-120km/h)
- Timestamp train identification
- Total train weight + individual detection of vehicle, axle, wheel parameters
- Min. 7-meter-long measurement area in track
- Measurement of L(A)p,tp according to ISO3095 [1] + saving of raw rail acceleration + microphone data for postprocessing

Selection of the installation sites needs to be studied in detail for several reasons, steered both by the weighing and the noise emission part.

1.1 Requirements for the weighing part & general installation

Following aspects should be considered:

- Long term planning of track renewal (to avoid reinstallation in short time)
- Speed restriction possible after placement (until ballast stabilization)
- Possibility to get track out of service / period / ETCS restrictions.
- Reference Speed
- Non-braking zone (signaling)
- No slope in track
- Track rigidity (EV2 better then 60 Mpa)
- Track composition (rail UIC60E1, sleepers M41, fixation Pandrol clips, stiff EVA rail pad)
- No welding, discontinuities in rail
- Out of the stressing zone of the track (at least 150m from dilatation devices)

1.2 Requirements for the Noise-Vibration emission part

Following aspects should be considered:

- High and temperature independent track decay rate by using stiff rail pads (EVA)
- Low and well-maintained rail roughness
- Reference track section (ballast/walk pad/concrete bunkers) within regulation with no significant reflecting objects within 22 m around microphones.
- No excessing noise emission from other sources (< min. train emission – 15 dB)

Ruggedized, double isolated accelerometers that measure the vertical rail vibration as close as possible to the sleeper, using specially designed resonance free mounting clamps are used. The microphones are installed at 7.5m from the center of track according to the ISO3095. Both accelerometers and microphones are installed permanently. The raw data (sampled at 51.2 kHz) for both rail acceleration and sound pressure is simultaneously triggered, sampled, and stored for the complete train pass by, to be used for automated post processing.

2. METHODOLOGY AND IMPLEMENTATION OF SOFTWARE FOR ROUGHNESS CALCULATION

2.1 Principle

The software was introduced in several steps. In a first step the TNO- PBA software was tested. For details we refer to the website at TNO Delft for manuals and software[1].

[1]https://www.tno.nl/media/2476/pass-byanalysissoftware_tno_81257.pdf

Figure 1 refers to the used approach in the PBA software. The goal of this paper is not to explain in all detail the methodology, but to show results of the application of the software. A “single value indicator for combined roughness” is used to identify and display a global roughness value. The methodology was in the test phase applied to more than 1000 train pass-by’s. Only some examples are given in this paper.

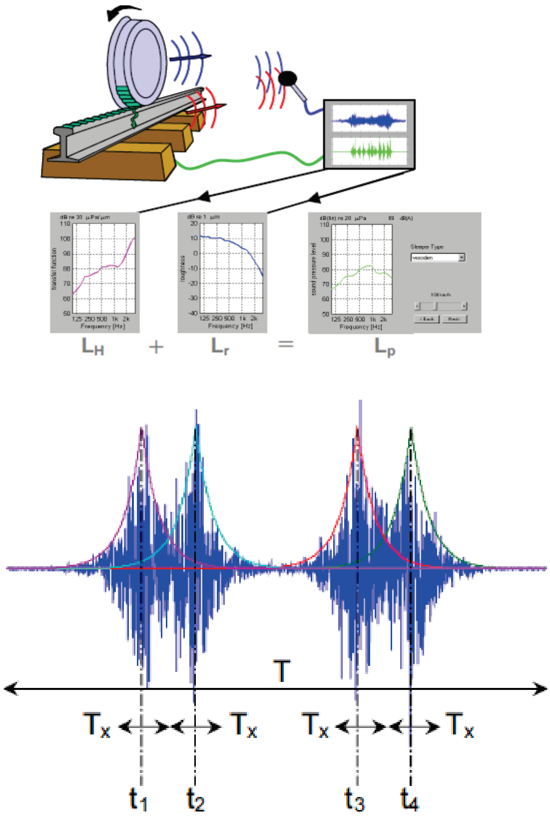

Figure 1. Schematic overview of the analysis procedure in PBA software.

2.2 Implementation in post processing

In a second step the standard TNO-PBA-software was upgraded towards an automated version. It is extremely important to detect with great accuracy the presence of the axle in the timeframe of the acceleration data. (See Figure 1: t1, t2, t3, t4). That was rather easy because the vibration data and the axle presence can be perfectly synchronized by the weighting bridges. This leads to a fast estimation of the wheel roughness, not only the Single value indicator, but

also the roughness versus wavelength one-third–octave spectra.
Figures 2 show the visualization of the rail acceleration with indication of axle presences for a typical freight train passage.

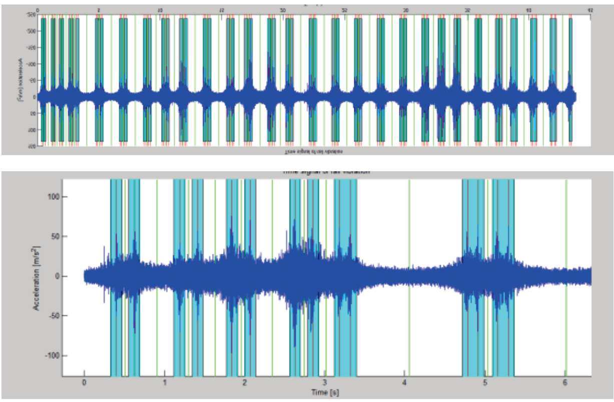

Figure 2. Vertical acceleration and indication of axles top: whole train pass-by, bottom: zoomed on 14 axles.

Figures 3 and 4 show respectively the one-third–octave roughness spectra versus wavelengths and the Single value indicator for roughness for each axle of the train passage.
In Figure 3, typical dominant wavelengths can be identified, axle by axle. Figure 4 clearly shows the roughness differences axle by axle.

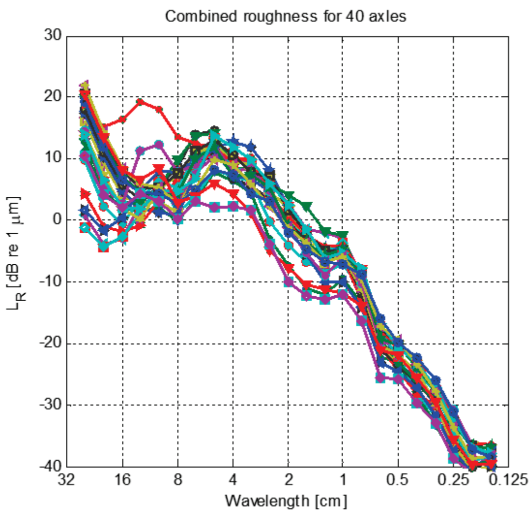

Figure 3. Combined Roughness versus one-third–octave spectra wavelengths for a 40-axle train.

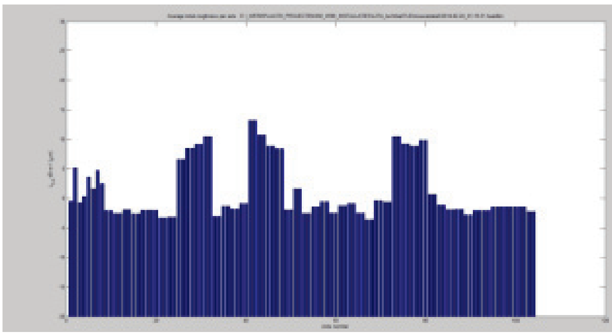

Figure 4. Single value indicator for roughness for a complete freight train.

2.3 Correlation between breaking block and wheel roughness

2.3.1 Validation at standstill

It is well documented that there is a huge difference in wheel roughness based on the type of braking block[2] [2]. A visual inspection is shown in Figure 5. A composite brake block shows a hole in the mounting lip. This is easy at stand still, but for a running train it is more complex. Therefore, during the validation of the implementation a high-speed camera campaign was organized in order to detect the type of brake blocks of running trains.

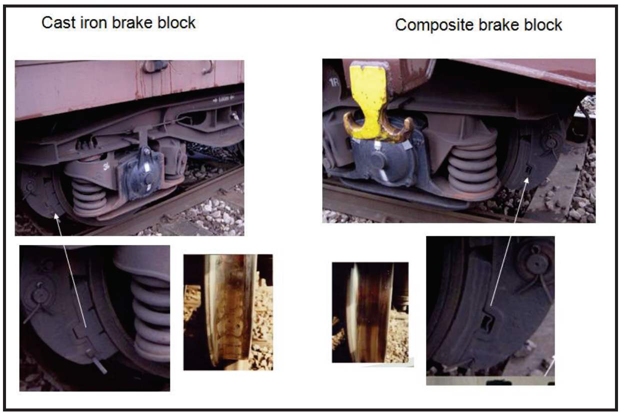

Figure 5. Visual recognition between cast iron and composite brake block.

[2] http://uic.org/IMG/pdf/railway_noise_in_europe_2 016_final.pdf)

2.3.2 High speed camera

For several days a Cyclocam high-speed camera, capturing 500 images/second was installed near the tracks. Figure 6 shows a typical image of a view on the braking blocks of a running train.

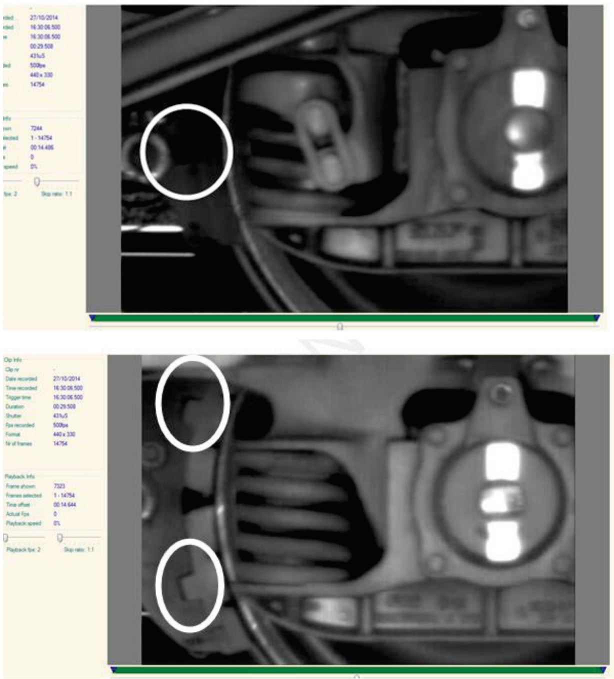

Figure 6. Visual recognition between brake blocks, upper: composite, lower: cast iron.

2.4 Validation results

The camera data was used to link the images with the estimated type of brake blocks by the software. Figure 7 shows an example of a detailed validation for one train passage.

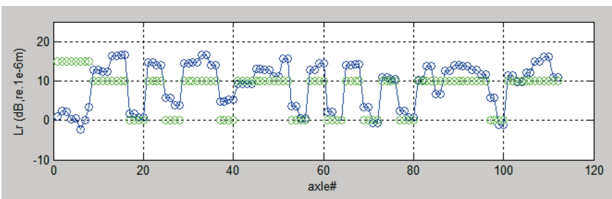

Figure 7. Visual recognition versus Single value indicator for roughness estimate derived from rail acceleration.

In blue dots, the Single value indicator for roughness is plotted, while the green dots representing the high-speed camera information: 0 -> recognized composite block, 10 -> recognized cast iron block, 15-> brake block not visual.
For cases where the brake block is visual in the images, a very good correlation between the recognized brake block type and the estimated one from the calculation (better than 99%) was seen. That is the proof that the detection of the type of brake block is feasible.

3. REAL TIME IMPLEMENTATION

The type of brake block will then be one of the parameters generated by the system outputs. It will be written and becomes available in XML format on the network server within 30s after the train passage. Futher validations where organised by manually measurement of individual wheel roughness and with high speed cameras.
Figure 8 shows a verification plot, used within the validation process, where we compare in the middle plot the results achieved by TNO-PBA (red) and by the optimized processing routines for a typical freight train with 102 axles. The differences can be understood by the fact that TNO-PBA normalises the wheel roughness per bogie. Care is to be taken when a wheelflat is present on a wheel, since that results in wrong roughness estimation. These estimation are to be ignored. The lower plot classifies the roughness in 4 classes which are represented by lines with circles on the values. In the header of the last graph we see that 22 axles are equipped with composite brake blocks.

Today, the automated calculation of the wheel roughness, and so type of brake block detection is implemented and running in 15 double track installation. It is used to count the number of retrofitted axles present on the network. That parameter can be used to estimated the effect of the retrofit on the global noise emission reduction of the network. Also the system can be used to verify the by the operator declared number of retrofitted brake blocks.

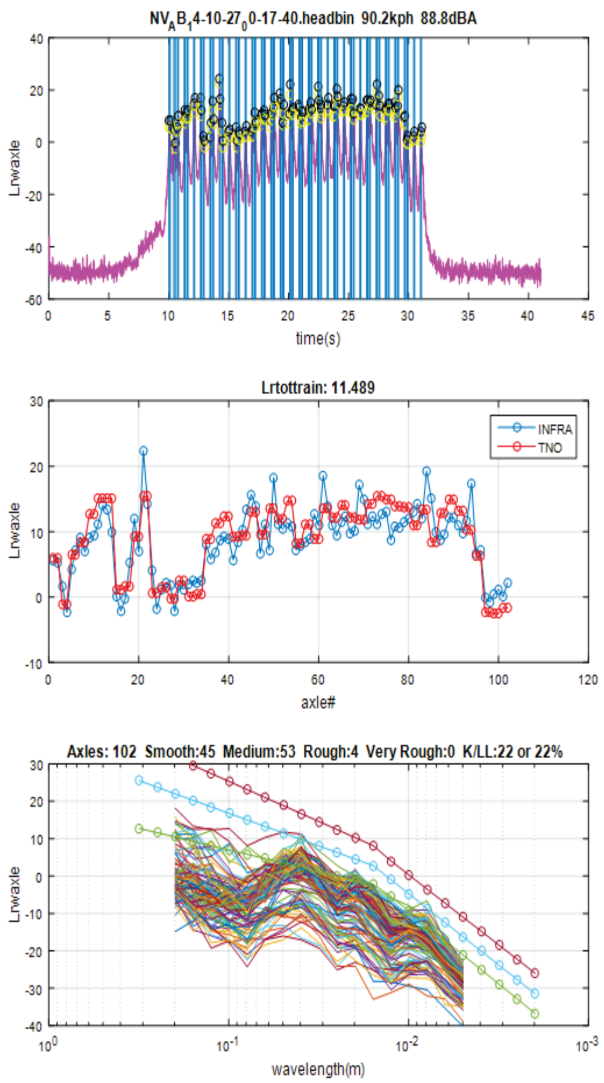

Figure 8. Graphical representation real time processing result / estimation of number of retrofitted axles.

4. CONCLUSION

The presented approach of estimation of individual wheel roughness by combination of a W.I.M system with N&V monitoring is implemented and running on 15 double track installations. The output is amongst others used for the detection of the ongoing retrofit of existing freight wagons. Other advantages can be that the % of retrofitted axles can be used as an input for noise mapping according to the European Directive 2002/49/EC. Taking in to account the correct values will significantly upgrade the quality of each noise mapping project. Towards citizens, automated measurements and detections can be used to communicate that the noise emission reductions due to the retrofit is significant.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] ISO3095:2013

[2] Paul de Vos, UIC, “Railway Noise in Europe - State of the art report,” p.24