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# ANALYSIS AND DIAGNOSTICS SOUND SOURCES OF WHEEL LOADER BY THE VISUALIZATION METHODS

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**Abstract:** The paper deals with analyses and diagnostics sound sources of wheel loader. A unique acoustic camera measuring tool was used for the measurement. Noise visualization tool – acoustic camera is taking an image of the noise emitting object. At the same time are exactly computed by the special developed software sound map and combines the acoustical and the optical images of the sound source. Results of noise visualization enable diagnostics of critical components and provide background for constructors for noise reduction measures. The paper is focused on the identification and localization of wheel loader noise sources. Measurements were made to identify the dominant sources of wheel loader noise in order to reduce wheel loader emissions. The created acoustic images of the wheel loader and its parts serve together with the frequency analysis as a basis for further analyzes. Based on these analyzes, the components that causes excessive noise will be identified. The aim of the performed measurements was to point out the critical components that need to be focused on when making adjustments to reduce noise.
**Keywords:** noise visualization, wheel loader, dominant frequency

## 1. INTRODUCTION

For the diagnostics purposes and analysis and for the identification and localization of noise sources, a unique device for noise visualization - an acoustic camera - was used. This modern tool is suitable for complicated measurements of large noise sources for the purpose of their identification and subsequent quantitative and qualitative analysis [1,2].

The set of devices forming the acoustic camera is a revolutionary solution for the spatial localization of noise emissions with their quantitative evaluation and frequency analysis in dynamic mode. The amount of information obtained and analyzable is incomparable with all the methods used so far, which consisted in measuring noise emissions around the source, the number of measurement points is considerably limited. The acoustic camera offers the possibility of perfect frequency analysis of noise sources at a distance of 1 meter to several tens of meters. The supplied software equipment can effectively locate noise sources, perform qualitative and quantitative analysis and thus create a basis for measures to reduce noise emissions.

The whole measurement and subsequent analysis is characterized by [3,10]:

- ≡ high accuracy,
- ≡ high speed,
- ≡ dynamic mode of work,
- ≡ high efficiency,
- ≡ clear processing of results (color noise maps, videos, sound recordings).

## 2. MEASUREMENT PROCESS

The measurements were performed outdoors on a flat reflective asphalt surface. A view of the wheel loader and the installed acoustic camera is shown in Figure 1.


Figure 1. Wheel loader and installed acoustic camera

Noise sources visualization measurements of the wheel loader were performed with an acoustic camera. This device visualized all the most significant sources of noise. Spectral analysis of these sources was also performed to better understand the character of noise sources [6,7].

Measurements were made focusing on the front loader as a whole from all sides. Subsequently, measurements were performed with a focus on the drive system with the wheel loader uncovered from several sides and when lifting the bucket. The passing of the wheel loader from two sides were also visualized. Measurements were performed at an engine speed of 2500 rpm. All critical acoustic events were captured during the measurements. Measurements were also performed with a sound analyser to record other acoustic descriptors [4,5,]. Selected measurements are presented in the paper.

## 3. RESULTS OF NOISE VISUALIZATION MEASUREMENTS

The following images present selected results of measurement and visualization of the dominant noise sources of a wheel loader. The results of the visualization are presented in real images, in some cases, they are shown in outline format for better display. For each measurement, a spectrogram was made, from which it is clear which frequencies are dominant. Acoustic images were created for the entire frequency spectrum and, if necessary, on the basis of information from the spectrograms for individual dominant frequencies.

In Figure 2 presents the results of noise visualization in a side view of a wheel loader.

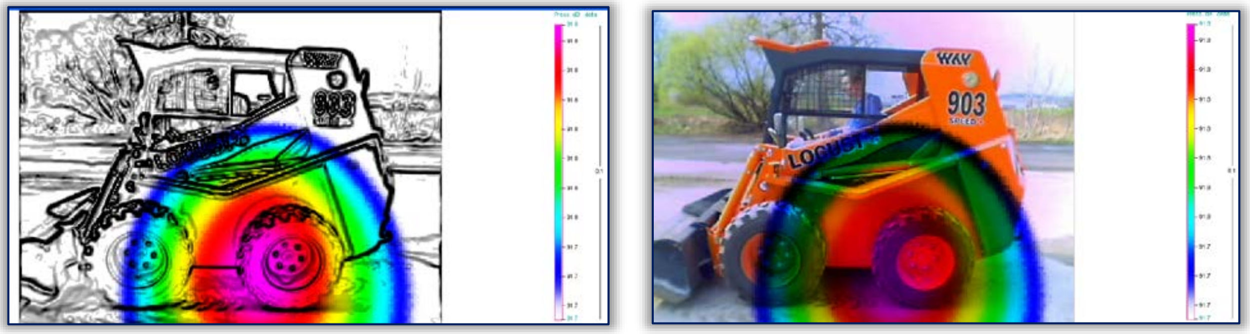


Figure 2. Noise visualization in whole frequency spectrum – side view

In Figure 3 is a noise spectrogram from the side view measurement. The dominant frequency areas are evident from the spectrogram. Subsequently, it is possible to create acoustic images at these frequencies, from which it will be clear from where the sound of a given frequency is emitted [8,9].

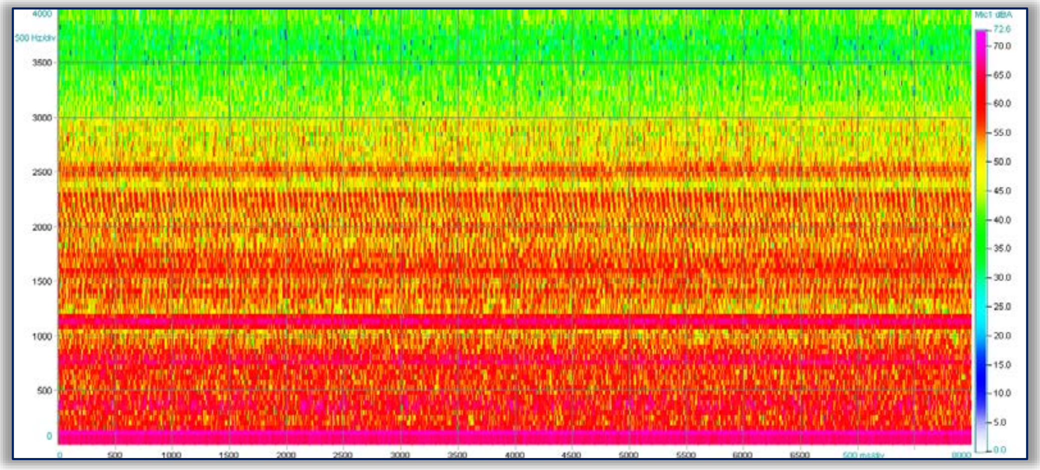



Figure 3. Noise spectrogram – side view

In Figure 4 presents the results of noise visualization in measurements focused on the drive mechanism of a wheel loader.

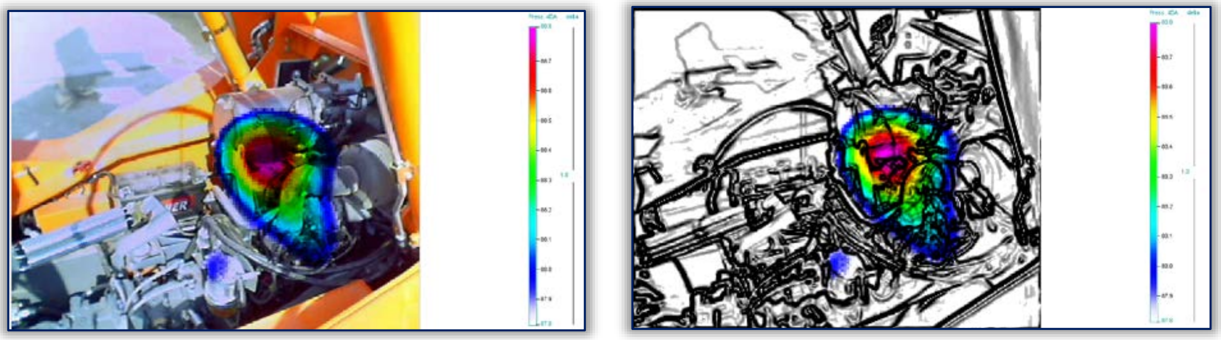


Figure 4. Noise visualization in whole frequency spectrum – drive unit

In Figure 5 is a noise spectrogram acquired during the measurement of drive unit. The dominant frequency areas are evident from the spectrogram.

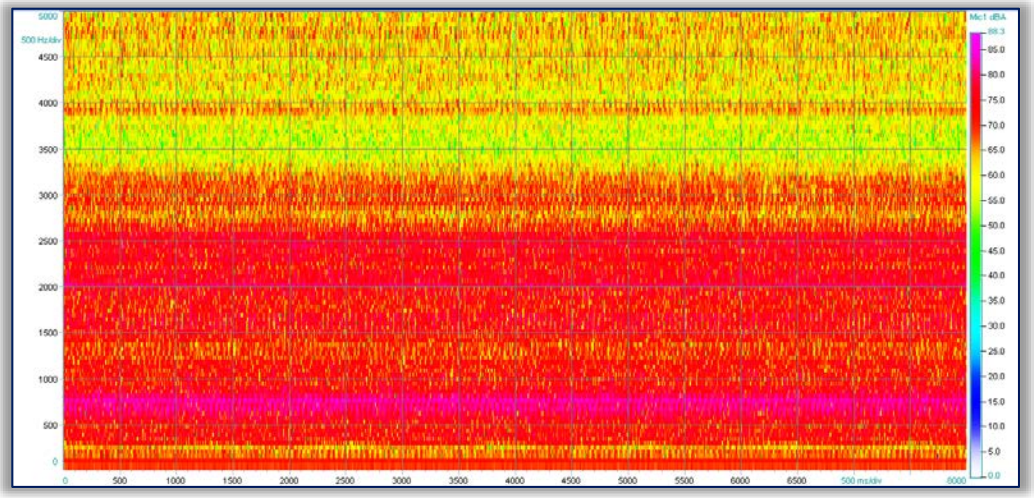
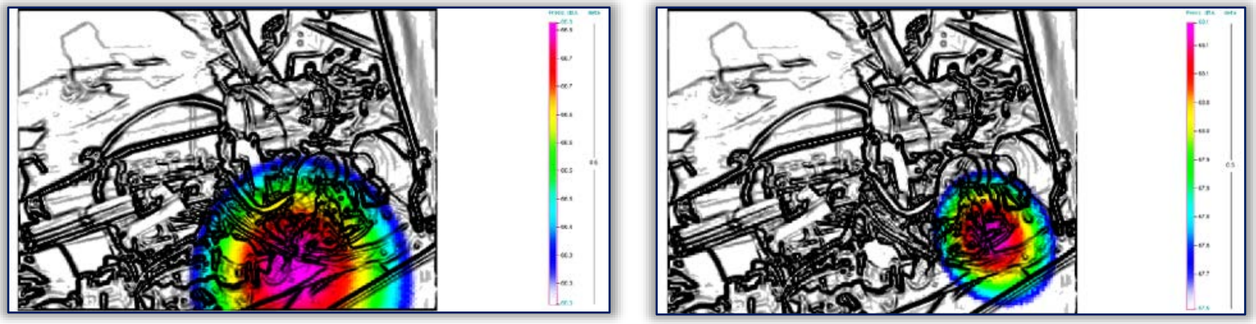


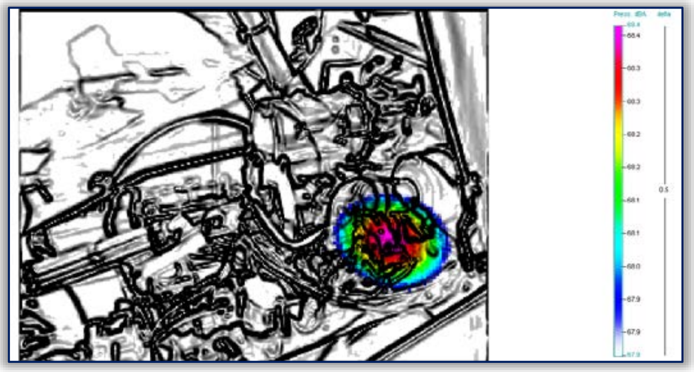

Figure 5. Noise spectrogram – drive unit

Subsequently, based on the spectrogram, dominant frequency areas were identified. Acoustic images have been generated for these frequency bands, which locate and identify sound emission with the appropriate frequencies. In Figure 6 and 7 shows sound emissions at frequencies 291, 540 and 831 Hz.



291 Hz 540 Hz

Figure 6. Noise visualization for selected frequency bands 291 and 540 Hz



831 Hz

Figure 7. Noise visualization for selected frequency bands 831 Hz

## 4. CONCLUSIONS

Noise visualization makes it possible to diagnose critical points in terms of noise emissions. The application is especially suitable for complicated noise sources. The result of the visualization is an acoustic image from which it is possible to identify and locate critical points. It is also possible to perform a quantitative and qualitative analysis of partial noise sources. It is possible to identify dominant frequencies from spectrograms and by creating acoustic images it is again possible to locate components that emit given frequencies.

During the wheel loader measurements, noise transfer points through the wheel loader body were identified, and measurements were made from all four sides. The decisive source of noise is, of course, the drive unit. For this reason, measurements were performed focusing on individual parts of the drive unit system. The noisiest parts of the measurements were found and the subsequent frequency analysis identified the components that emit noise in the dominant frequency bands.

Only selected measurements are presented in the article. The implemented measurements diagnosed critical points and components in terms of noise emissions and serve as a basis for developers and designers. Based on these measurements, it is possible to subsequently implement measures to reduce noise (installation of damping materials, change of the construction of the body, replacement of problem components).

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**References**

[1] Döbler, R. D: Time Domain beamforming using zero padding, In: Berlin Beamforming Conference (BeBeC), 2008.
[2] Döbler, D; Heilmann, G: Perspectives of the Acoustic Camera, In: Environmental Noise Control". In: The 2005 Congress and Exposition on Noise Control Engineering, 2015, pp.1-9.
[3] Fedorko, G; Liptai, P; Molnár, V: Proposal of the methodology for noise sources identification and analysis of continuous transport systems using an acoustic camera, In: Engineering Failure Analysis, vol. 83, 2018, pp.30-46.
[4] Liptai, P: Dynamic noise Visualization by the acoustic camera, In: Environmental Management and Engineering, TU Košice, Slovakia, 2007, pp. 269-276.
[5] Moravec, M; Badida, M; Jamborova M: Conveyor failure diagnostics using sound visualization technique, In: Advances in science and technology research journal, vol. 12, issue 4, 2018, pp.144-150.
[6] Moravec, M; Liptai, P; Dzuro, T: Design effectiveness verification of sound reduction measures in production hall, In: In: Advances in science and technology research journal, vol. 11, issue 4, 2017, pp.220-224.
[7] Moravec, M; Liptai, P; Badida, M; Dzuro, T: Dynamic noise visualization methods for identification of noise sources, In: 14th International multidisciplinary scientific geoconference, 2014, pp.207-212.
[8] Moravec, M; Lumnitzer, E; Lukáčová, K: Application of acoustic camera for machine dynamic noise visualization and diagnostic and quality, Annals of Faculty of Engineering Hunedoara, Romania, 2011, pp. 31-32.
[9] Moravec, M; Liptai, P: Methods and progressive equipment for sound visualization of noise sources, In: Scientific Letters of Academic Society of Michal Baludansky. 2017. pp. 131-134.
[10] https://www.acoustic-camera.com



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