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The noise sources identification and noise reduction in the industrial plant

Wiesław Fiebig
Institute of Machine Design, Wrocław University of Technology, Wrocław, Poland.

Damian Dąbrowski
Wibro-Akustyka, Ostrów Wlkp., Poland

Summary

The paper presents results of the identification of noise sources in the industrial plant. Identification of noise sources was made with an acoustic camera using Beamforming method. On the basis of noise level measurements, main noise sources have been established (cooling towers, air intakes, windows in the technical building). Based on the calculations, forecast has been determined regarding the reduction of noise levels for residential buildings located near to the plant. Acoustic noise maps have been performed with LEQ Professional software, which includes the 3D geometry of the buildings inside the plant.

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1. Introduction

Industrial noise which occurs especially in the vicinity of residential buildings should be within the limits described in the regulation Dz. U. 8.10.2012 pos. 1109. If noise levels exceed the limit values for industrial installations a key issue is the location of the main sources of noise and application of measures designed to reduce noise emissions. This applies to both internal and external noise of industrial rooms.
In this work the location of the main external noise sources in the production plant has been done using an acoustic camera. Based on results, measures for noise reduction has been proposed. The noise emission in the residential area with using these measures has been reduced.

2. Noise sources location in the plant

For the location of noise sources an acoustic camera CAE-Noise Inspector has been used. The camera has a high resolution, especially in the field of medium and higher frequencies and allows location of the main noise sources as well as noise transmission paths.

The acoustic camera (Fig. 1) consists of a microphone array, video camera built inside the array, signal processing module and software for signal and data processing installed on a laptop computer. For the evaluation of measurement results the relevant numerical algorithms in LabVIEW were used. The 40 microphones are in the same plane and measurement takes place in the perpendicular direction to the array.

Fig.1. Acoustic camera CAE- Noise Inspector.

2.1. Beamforming method

The acoustic camera allows to convert sound levels to form the image. Thanks the visualization of sound levels in a optical picture or video, the fast location of noise sources is possible. Using the acoustic camera not only the sources can be located but also the sound levels generated by them.

The principle of Beamforming method [6] is based on a description of Delay-and-Sum beamformer. As shown in Figure 5, the measurement occurs in the plane and signals will be examined from M microphones located in sites r_m (m = 1, 2, ..., M) in the x-y plane of the coordinate system. When the plane will be applied for Delay-and-Sum Beamforming, signals measuring the sound pressure p_m shall be individually delayed and then added together:

$$b(\kappa,t) = \sum_{m=1}^{M} w_m p_m (t - \Delta_m(\kappa))$$

Where the coefficients b are a collection of w_m weights applied to the individual acoustic pressure signals p_m from individual microphones. Individual time delays Δ_m were obtained in order to achieve the higher sensitivity in a particular direction.

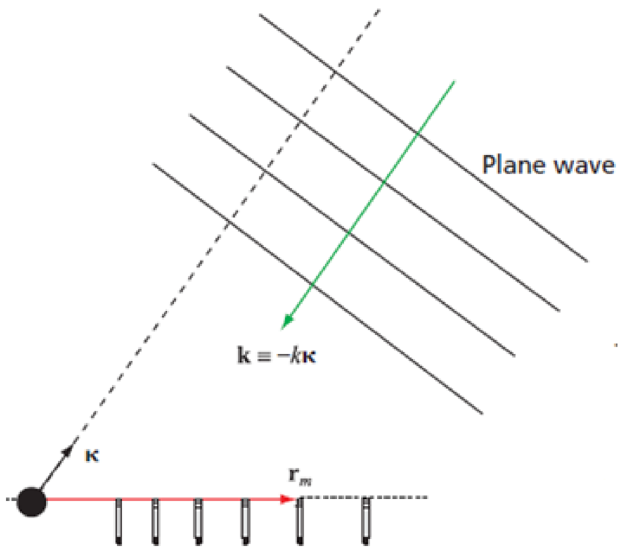

Fig. 2. The grid microphones, focused on the far field and flat wave coming from the focused direction.

The signals associated with the flat wave come from the direction of κ and are synchronized in the time before totaling. Geometric considerations (Fig. 2), show that this can be achieved through:

$$\Delta_m = \frac{\kappa \cdot r_m}{c}$$

Where c is the speed propagation of sound. Signals from other directions will not be compatible before totaling, so there will be added in a not coherent way. In this way, the directional sensitivity is specified, as shown in Figure 3.

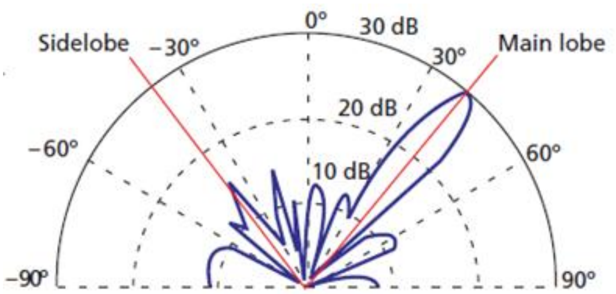

Fig. 3. Typical directional sensitivity profile with the main focused direction.

2.2. Measurement results

In Fig. 4-7 the results from measurements with acoustic camera has been shown. Three main noise sources has been identified:

- Source Z1- cooling and ventilation device (Fig. 4). The noise levels up to 88 dBA has been stated.
- Source Z2 - air intake inlet on a side of technical building (Fig. 5). The maximal noise levels up to 76 dBA has been observed.
- Source Z3 and Z4 - acoustic leaky windows in the technical building (Fig.6 and Fig.7) with maximal noise levels up to 76 dBA.

The measurements has been carried out in the night hours because the disturbing noise levels coming from the street near to the plant were lower.

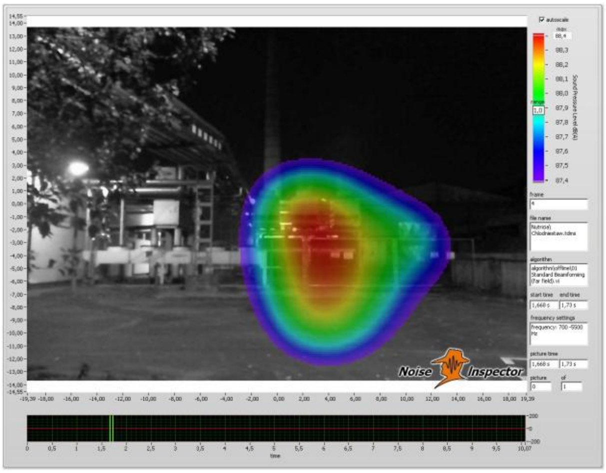

Fig.4. Source Z1.

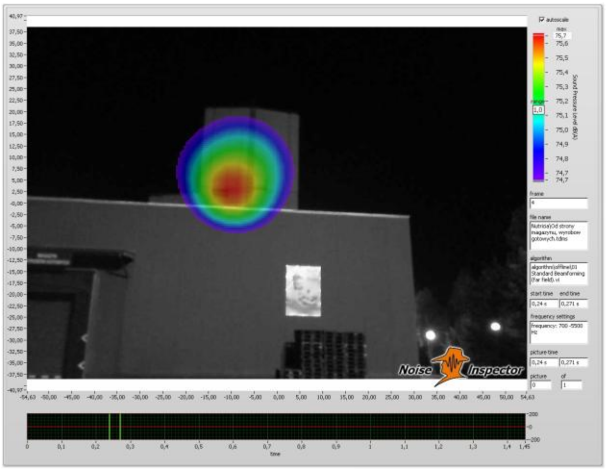

Fig.5. Source Z2.

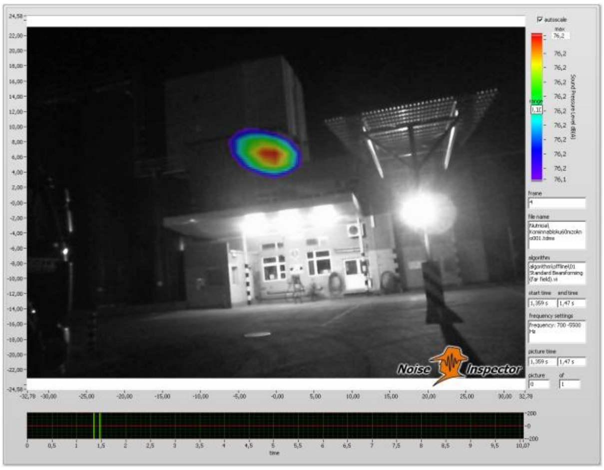

Fig.6. Source Z3.

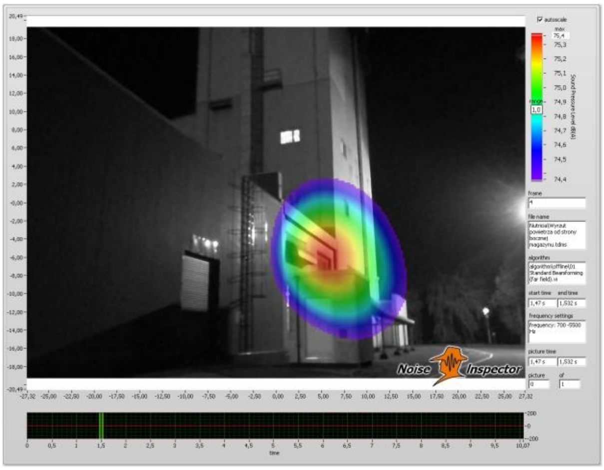

Fig.7. Source Z4.

Two of most important noise sources are shown on Fig. 8.

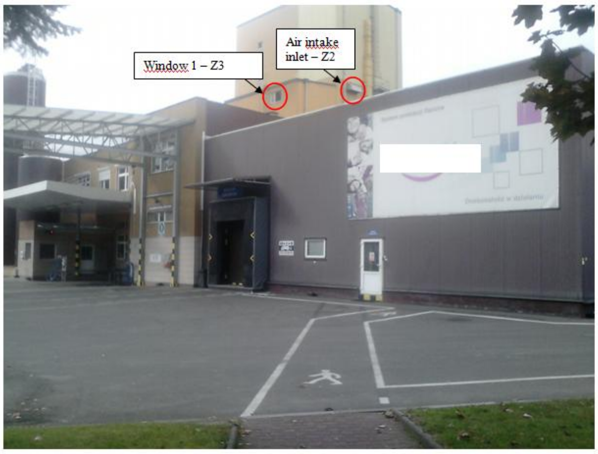

Fig. 8. Main noise sources Z2 and Z3.

2.3. Measurement with sound level meter

Additional to the measurements with the acoustic camera the equivalent sound level $L_{Aeq,T}$ on the measurement points (positions of the acoustic camera) has been established.

The sound level meter type 945A SVAN class 1 has been used. Sound level meter meets the standards EN-60651 and 60804. Before the measurement, the sound level meter has been calibrated.

The measurement of the sound level meter with the following settings was performed: A – weighting on, time constant Fast, measuring range-30-130 dB, type of the data stored into the buffer device – RMS.

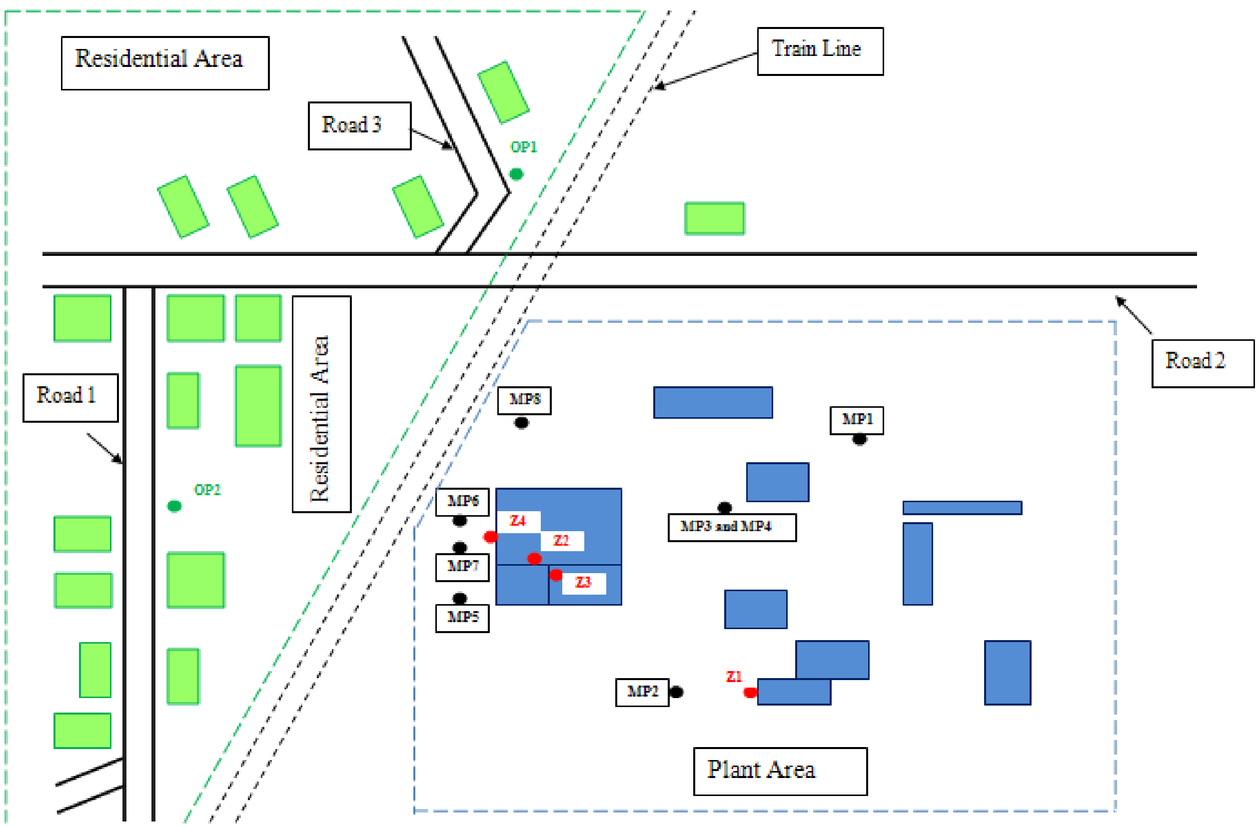

Fig. 9. Site map with measurement points and position of main noise sources.

In Fig. 9 the site map with marked position of the noise sources Z1- Z4, positions of measurement points MP1- MP 7 and observation points OP1, OP2 have been shown.

The equivalent A-weighted sound level is defined as an average sound level and carries the same energy as the noise source with a variable level and is expressed by:

$$L_{Aeq,T} = 10\log\left(\frac{1}{T}\int_0^T \frac{p^2{}_A(t)}{p_0^2}\,dt\right)$$

where:

p_A (t)- A- weighted sound pressure, Pa,

p_0- the reference pressure (2 • 10-5 Pa),

T-time, s.

$L_{Aeq,\ T,\ s}$ is the mean value of the equivalent level of

$$L_{Aeq,T,s} = 10\log\left(\frac{1}{n}\sum_1^n 10^{0,1*L_{Aeq,T,n}}\right)$$

"n" measurements, expressed by the formula:

where : n is the number of measurements.

$L_{Aeq,T,n}$- A- weighted equivalent sound level for "n" measurement, dB,

T-time, s.

Table 2.1. Sound level $L_{Aeq,T}$ [dB] in the measuring points from MP1 to MP8 (at the place of location of the acoustic camera).

Measurement point	Noise level $L_{Aeq,T}$ [dB(A)]
MP1	58,70
MP2	66,40
MP3	54,10
MP4	53,70
MP5	56,20
MP6	55,20
MP7	57,00
MP8	50,60

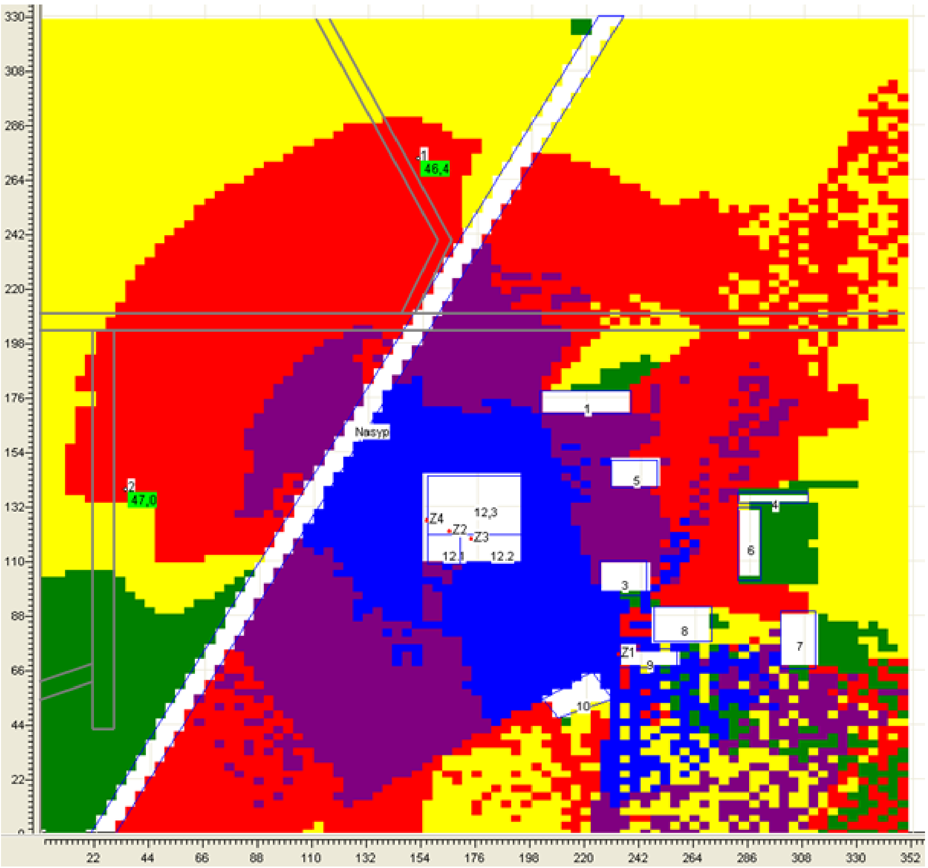

Figure 10. Acoustic map without noise sources reduction measures.

The residential area is located on the north side of the plant and should be protected against noise. The noise levels in the residential area were respectively OP1 (48,1 dBA) and OP2 (49,5 dBA). These values exceed limit values for residential area during the night (45 dBA). Due to that, the plant was obliged to reduce the noise levels below the limit value.

Following measures for noise reduction has been obtained:

- Capsulation on the air intake inlet with the acoustic damper – source Z2.
- Increasing the insulation of two windows in the facade of the technical building- sources Z3 and Z4.

3. Forecast of effectiveness of noise reduction measures

Based on measurement results calculations with the software LEQ Professional for the assessment of noise reduction using the proposed noise reduction methods have been carried out.

In Fig. 10 the acoustic map without noise reduction measures has been shown. It is to see, that the noise coming from the cooling and ventilation devices is acoustically shielded and it is strongly reduced in the direction of the residential area. While the noise emission from other noise sources (2 windows and air intake inlet) in that direction is relatively high. From Fig. 11 is to see that due to the introduction of noise reduction measures the predicted total noise in the observation points in the residential area are up to OP1 (43,9 dBA) and OP2 (44,3 dBA). Predicted noise reduction will be sufficient to meet requirements according to the regulation Dz. U. 8.10.2012 pos. 1109.

The effectivity of the introduced measures has been also verified experimentally. At the observation points OP1 and OP2 the noise levels respectively 44,8 dBA and 44,7 dBA has been measured.

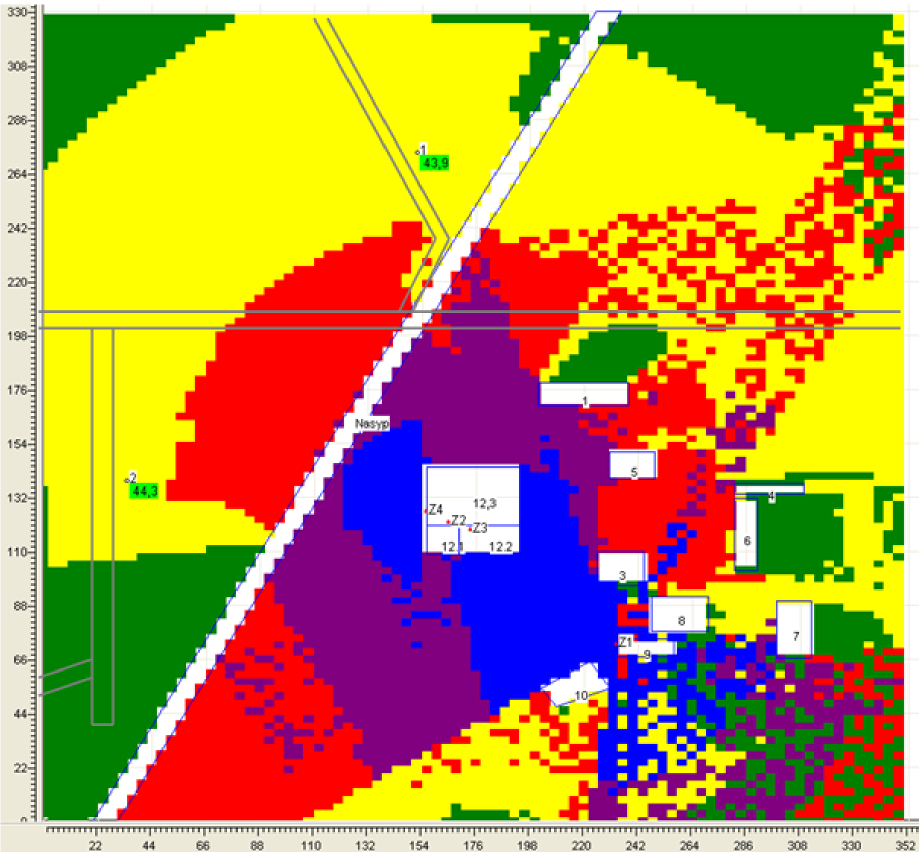

Fig.11. Acoustic map with assumed noise reduction for sources Z2, Z3 and Z4.

4. Conclusions

Acoustic maps were made on the basis of the identification of noise sources using an acoustic camera.

The maps shown the influence of noise propagation from main noise sources. For the purpose of the simulation other sources of noise (road, rail, acoustic background) were not included due to small impact on the sound levels in the interesting observation points in the residential area, especially during the night.
The study presents the acoustic maps without and with introduction of the acoustic measures for noise reduction. In order to reduce the noise levels at observation points at 5 dB, it is recommended to perform the acoustic capsulation measure for source Z2 (the air intake inlet), for sources Z3 and Z4 (windows 1 and 2) on the technical building.

The noise levels at the observation points in the residential area after introduction of noise reduction measures meets the limit values prescribed in the regulation Dz. U. 8.10.2012 pos. 1109.

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