The influence of portable acoustic screens on the workers protection

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Abstract
The paper presents the problems of negative influence of high level of noise on the workers and the possibilities of application of portable acoustic screens for the protection of workers which are around of machines. In the paper the results of experiments with application of portable acoustic screens are compared with theoretical calculations based on known methods applied for the evaluation of effectiveness of screens.

Introduction

The noise generated by engineering machines operating in an open space, apart from a negative effect on the machine operators, is emitted into the environment thereby affecting another workers around the machines.

The noise created during the work of machines has an impact not only on the machines operators, but also on employees around. The measurements of level of noise showed that this level exceeds legal regulations. To decrease the negative impact of noise, portable acoustic screens can be used. The research of portable acoustic screens was conducted – in the first stage – on the reference source in the laboratory, and in the second stage, in real conditions. The results were presented during the X International Conference: “Ochrona człowieka w środowisku pracy”.

The aim of this paper is to compare the experimental results with the theoretically calculated values of IL of screens.

Negative effects of noise

A negative level of the noise emitted by machines should be considered from the health and economic aspect. Staying in the surroundings of a high level of the noise causes different effects, which are presented in the table 1.

<table>
<thead>
<tr>
<th>Physiological effects</th>
<th>Psychological effects</th>
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<tr>
<td>Hearing impairment</td>
<td>Discomfort</td>
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<tr>
<td>Vegetative function disorder</td>
<td>Stress, nervousness, tension</td>
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<tr>
<td>Cardiology problems</td>
<td>Weakness, depression</td>
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<td>Blood pressure increase</td>
<td>Problems with communication</td>
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<td>Light sleep</td>
<td>Reduced productivity</td>
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<td>Disapproval from others</td>
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<td>Aggressiveness</td>
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<td>Social segregation</td>
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</tbody>
</table>

Methods of noise reduction

Since noise is one of the commonest hazards to the environment, steps are taken to eliminate or reduce it by using appropriate means. These can be divided into two groups [1]:
– administrative and legal methods;
– technical methods.

The administrative and legal methods are based on establishing and enforcing appropriate acts and standards of a given country, as well as European directives and standards. Organisational activities aim largely at reducing the exposure of people to noise when the use of technical means is impossible.
Technical methods can be divided on passive and active methods. They are aiming at limiting or minimising noise emission, limiting the transmission of vibro-acoustic energy on its paths, and limiting noise emission on specified areas of the environment and a man by using appropriate technical solutions, personal protective devices and removing a worker from noisy processes.

Between the passive methods of the noise reduction, it can indicate the application of portable acoustic screens which help to protect the workers present around machines.

The effectiveness of portable acoustic screens was analyzed experimentally. The results of research were presented during the X International Conference: “Ochrona człowieka w środowisku pracy – Obsługiwanie maszyn i urządzeń – Zintegrowane systemy zarządzania: jakość–środowisko-bezpieczeństwo–technologia” (Świnoujście – Ystad – Świnoujście, 15–18 september 2011).

Experimental acoustic examinations of work machines were made on machines currently operating in the streets during road works. The earth moving machines were examined. Measurements of noise level emitted during machines operation were made according to the guidelines from PN-01341, PN-ISO 1996-1, PN-N-01307 [2]. Equivalent sound level A, \( L_{\text{Aeq,T}} \) was measured.

For the researches the following machines were selected:

- circular saw TRAg 180AR, 1400 W, 7000 obr/min., (saw A);
- circular saw PERFORMANCE POWER NT 2200M (2200 W), (saw B);
- circular saw for wood BHS 55, (1020 W, 4000 obr/min.), (saw C);
- rotary hammer BOSCH, 1350 W, GBH7-46DE;
- compactor WACKER 2 KW – vertical;
- compactor Honda 4 KW – horizontal.

The results of measurements during the work of these machines indicate a considerable excess of admissible values.

In the next stage of the researches the measurement of noise generated during the work of these machines with the use of models of acoustic screens and acoustic curtains were made.

The researches of acoustic efficiency (IL) of six models of acoustic screens allowed to determine the average value of IL and to assess the impact of various factors on the noise levels reduction. Four models of screens – selected after the several measurements – represented the following average values of IL at a distance of 1m from the screen (Fig. 1) [3]:

- model of screen I: 8–9 dB;
- model of screen II: 8–10 dB;
- model of screen III: 9–10 dB;
- model of screen V: 9–14 dB;
- model of screen VI: 12–18 dB.

![Fig. 1. Comparison of the levels of reductions of noise emitted by the saw for wood after the application of different screens](image)

### The theoretical determination of acoustic screens effectiveness

#### Value of Insertion Loss

The acoustic effectiveness of screen is a value which permits to determine the effectiveness of screens possibilities to shield. This value is defined like the difference of noise level in the observation point before and after the application of screen.

\[
\Delta L = L_1 - L_2 = 10 \log \left( \frac{P_1^2}{P_2} \right) \quad \text{[dB]} \quad (1)
\]

where:

- \( L_1 \) – level of acoustic pressure in the measurement point without screen;
- \( L_2 \) – level of acoustic pressure in the measurement point with the screen;
- \( P_1 \) – average value of acoustic pressure without screen;
- \( P_2 \) – average value of acoustic pressure with screen.

#### Methods of Insertion Loss determination

The methods of calculation of sound absorbing for big screens (generally of the effectiveness of screens possibilities to shield) are used for the protection from communication noise. The methods used most often are:

- method of Rettinger;
- method of Redfearn;
- method of VDI-2720;
- method of Delany;
- method of Mackawa.
a. Method of Rettinger

According to Rettinger’s method, the effectiveness of screens possibilities to shield depends on indicator \( w \), which is determined for three positions of the source and the observer. This indicator depends on dimensions of screen and on place of a source and a recipient. For example, for the source and recipient on the different levels (like in case of investigated machines), the indicator is:

\[
w = \left( H + \frac{b(H-h_1)}{a} - h_2 \right) \left( \frac{2a \cos \alpha}{b(a+b)} \right)
\]

where:
- \( H, h_1, h_2 \) - heights of screen, source and observer;
- \( a, b \) - distances between source and screen and between source and observer;
- \( \alpha \) - angle between the lines source-edge of screen and source-observer.

![](relation_source_receiver.png)

Fig. 2. Relation source-receiver used in the Rettinger method [4]

The effectiveness of screens possibilities to shield can be determined thanks to the Rettinger graph basing on the indicator \( w \). This method is used for sources-points. The results of this method are very optimistic. In this method, the character of source is not specified.

b. Metod of Redfearn

The calculation of the effectiveness of screens possibilities to shield for source-point and linear source is possible according to Redfearn’s method. For this methods, the indicator is the difference of ways of waves radius (the wave deflected on the screen’s edge and the direct wave \( \delta \)). For source-point, the number of Fresner is the indicator:

\[
N = \frac{2\delta}{\lambda}
\]

for this method, the author assumed that \( \lambda = 0.5 \) m and it is a wave which is dominated in noise spectrum.

For above mentioned indicators, the effectiveness of screens can be determined grace to the Redfearn graph.

c. Method VDI-2720

The method VDI-2720 is recommended for the free field. The methods of calculations are base on the logarithms and are presented in the tables. In this method, there are two corrections. The first correction takes into account the position of the source and of the recipient. The second takes into account the reflection of sound waves and theirs diffusion between the source and the screen. This method does not take into account the notions of model’s sources. The method suggests that the sound’s source is linear.

d. Method of Delany

The method of Delany is applies to the determination of\( \text{IL} \) for source-point and linear source. For each source, there are the graphs \( \text{IL} \). For the source-point, there is the function for Fresner number:\n
\[
N = 2 \frac{\delta}{\lambda},\text{ for linear source, there is the function of } \delta.\text{ The symbols which concerning the geometry of relations: source-screen-observer are the same like in the Redfearn method.}
\]

e. Method of Meakawa

The most popular method using for the determination of screens IL is the method of Meakawa. During the investigations concerning diffraction of acoustic wave, Meakawa determined a relation between IL and Fresner’s number. The value of IL can be determined grace to Meakawa’s graph or empiric formulas (Fig. 3). These methods are based on the investigations and experiments which were made with existing structures. Meakawa method is applicable for point-sources and linear sources. The value of IL for different values of Fresner’s number is (approximately):

\[
\begin{align*}
\text{IL} &= 10 \log(20N) \quad \text{for } N \geq 1 \\
\text{IL} &= 10 \log(N+13) \quad \text{for } N \leq 1 \\
\text{IL} &= 10 \log(3+20N) \quad \text{for } N > -0.1 \\
\text{IL} &= 0 \quad \text{for } N \leq -0.1
\end{align*}
\]

![](fig_3.png)

Fig. 3. IL according Maekawa method [5]
Comparison of the value IL determined experimentally and calculated theoretically

The models of acoustic screens investigated experimentally, are different that the screens which are used to decrease the noise of streets and speedways. There are the differences concerning the geometry of screen. The communication’s screens are bigger because their height is always bigger than the height of source. During the investigations concerning engineering machines, the height of machine was often similar to the height of screen. However even when \( N < 0 \), (i.e. \( \delta < 0 \)) and the source is visible in the measurement point, the screen works in the theory as well as in practice. The conditions during investigations were also different, the screen was placed between a machine and a pavement, so there was supplementary another source of noise – communication noise. Despite these differences, it is proper to compare the results of IL calculations of screen’s models with the results of investigations. The comparison of different methods of IL calculation and results of the investigations are shown in table 2. The calculations were made for real position of sound’s source for chosen screen and for pneumatic drill \( (N = 0.96 – p. 1 \) and \( p. 2, N = 0.65 – p. 6) \). The calculation were made for \( \lambda = 0.5 \) m.

The differences between the theoretical and experimental values are considerable. It is on an average 30% of calculated value IL. For the Maekawa’s method the differences between the calculations of IL and the measurements are the least. The calculation’s methods which were applied are intended for communication’s screens. The presented differences between theory and experiment show the necessity of introduction of indicators. These indicators should take into consideration the specificity of work’s conditions of engineering machines and screens.

Conclusions

The investigations of noise level of engineering machine’s which work on the streets and of screen’s models used to decrease the noise level give the following conclusions:

- The noise emitted in the environment by the engineering machines exceed Polish Standards and European Union Directives concerning the permissible values of the noise level. The transgressions of the noise level at a work-place ranged from 0 dB to 17 dB. The transgressions of the permissible noise level in the environment during the work of the engineering machines ranged from 25 dB to 42 dB.

- The application of acoustic screens to decrease the level of noise emitted to environment by working machines is reasonable. The reduction of noise level after application of portable acoustic screens is from 8 to 18 dB.

- The presented methods of calculations of IL are dedicated for communication’s screens. The differences between theory and experiments show the necessity of introduction of indicators which take into consideration the specificity of work’s conditions of engineering machines and portable acoustic screens.

References


Others