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ASSESSMENT OF THE ACOUSTIC MICROCLIMATE AND RATING OF NOISE HAZARDS IN THE INNER TRANSPORT SYSTEM OF A BUCKET WHEEL EXCAVATOR: A CASE STUDY

Summary. Noise and acoustic microclimate have an important influence on working conditions in industry. However, there are many sources of noise in machinery that create occupational hazards. In particular, these problems occur in belt conveyors, which are components of integrated continuous material handling systems. In large heavy-duty machines used for surface mining (bucket wheel, bucket chain excavators, and stackers), the most acoustically active areas are located in the zones of conveyor lines. For this reason, the present article presents the results of comprehensive research of noise in a transport system in a bucket wheel excavator operated in a surface mine. The most significant sources of noise were tested. Two analysis approaches (deterministic and probabilistic) were applied. Lower values of permissible exposure time were obtained using the latter method. This approach should be selected, as it takes into account the real conditions of operation of the tested object. The research and analysis showed that in real operating conditions of large working machines (multi-bucket wheeled excavators), the noise level cannot be treated in deterministic categories. This is due (among other factors) to the fact that the working loads are randomly variable in various operating conditions, which also causes the nature of noise in the area of these machines and their surroundings to change randomly. For this reason, the acoustic climate and the assessment of the level of noise hazards in such machines should be analyzed by taking into account the random nature of noise.

1. INTRODUCTION

The problem of noise emission in the environment is of great importance. This problem is especially observed in large working areas like mines, quarries, pumped storage power stations, and other industrial factories [2, 3, 17-19, 26, 29, 30, 37, 38, 40, 41] characterized by the simultaneous presence of two factors. The first factor is machinery or equipment with a high level of noise emission. The second is that these places are extensive and difficult to surround with acoustic screens.

Moreover, the staff of such working places is extremely exposed to the negative influence of noise. According to different studies, many organs and systems in the human body can be harmed when exposed to excessive noise. Among these, the most important are the cardiovascular system [20, 25], nervous system (even influences on intelligence have been observed [36]), and respiratory system [13].

The influence on the condition of the nervous system can cause temporary irritability and distraction, which can impede normal work and eventually lead to accidents. In this way, noise effects

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can additionally affect health indirectly. Hearing loss is another typical consequence of noise exposure. It is estimated that the extended influence of noise around 100 dB results in permanent hearing loss. Similar results have been observed when people are exposed to noises of around 120 dB for a short period [5, 18, 21, 29]. Moreover, noise with a frequency below 2 kHz is especially dangerous to the hearing system [2], and such noise is typically produced by common industrial devices like belt conveyors. Taking this into account, a belt conveyor was selected as one of the research objects in this article.

Because of the abovementioned consequences, the level of noise at workplaces and industrial areas is recommended to be controlled [11]. New solutions for lowering noise should be implemented whenever possible. In all cases, the application of protective equipment must be considered. The localization of main noise sources plays a fundamental role in reducing noise [8]. It is also recommended that the diagnostic procedures applied to industrial conditions should include failure analysis. This kind of analysis is especially important in the mining industry, where complex machines such as excavators and conveyors are used [4, 14]. The impact that typical defects have on the work of the tested machines should be taken into account to distinguish the most crucial failures [39]. Similarly, different techniques that can be used in mines, processing plants, and other such industrial factories can cause distinctive types of noise [7].

On a positive note, some efforts have been made to develop new techniques for operating machinery as well as measures for protecting people, which lowers the level of noise, among other factors, in mines [24, 28]. Such improvements are especially important as people are usually exposed to the highest level of noise during work [15]. Therefore, lowering the influence of noise where it is the highest can have the greatest benefits to human health.

In addition to the influence on the environment and human health, the noise emitted by machinery can be tracked for diagnostic purposes as the deterioration of the technical state increases noise emissions (e.g., in conveyors) [23]. Other factors, such as the velocity of the belt or idler roll surface) also influence the level of noise [4].

The acoustic microclimate is an important factor of workplaces in the industry. It relates in particular to large heavy-duty machines used for surface mining (e.g., bucket wheel and bucket chain excavators and stackers) equipped with high-power drive units.

However, these machines are operated under severe environmental conditions 24 hours per day, seven days per week. Thus, this machinery is subjected to various degradation processes (e.g., material fatigue, corrosion, creep deformation, abrasive wear). One of the most apparent symptoms of degradation is increased noise levels, which frequently exceed the limits specified by appropriate standards. This may negatively influence the acoustic microclimate and cause noise hazards.

The relatively high noise level in large surface mining machinery is due to the high power drive units installed in these machines. For example, the bucket wheels in medium-size excavators are powered by 500 kW (or more), and the belt conveyors installed on booms are powered by engines of 300 kW (or more). According to the European Union's recommendations, the highest accepted noise level (L_{WA}) emitted by an individual sound source depends on the machine type and the built-in power of drive units. In particular, for an excavator, the noise level should not exceed the value indicated by the following equation:

$$L_{WA} = 80 + 11 \cdot \log P \tag{1}$$

where P is the total built-in power (in kW) of the drive unit.

Taking the above discussion into consideration, much research on many large machines used for surface mining has been performed. The present long-term research has been carried out under the guidance of Prof. Dionizy Dudek from the Faculty of Mechanical Engineering at Wroclaw University of Science and Technology. Some of the results of this research are presented in this article. The acoustic microclimate in selected zones of the inner transport system of material in a bucket wheel excavator was studied, and the noise hazards were evaluated.

The high intensity of vibroacoustic processes in long-term operating machines is not only a threat to the staff and the environment but also a symptom of the degradation of these machines as a result of (among other factors) working loads, deterioration of the strength properties of elements of loadbearing structures (corrosion, cracking, and abrasive wear), and aggressive environmental impacts, including precipitation and negative temperature. Monitoring the noise and vibration levels can aid the ongoing assessment of the technical conditions of such facilities and appropriate operational decisions. There is an enormous field of activity for vibroacoustic diagnostics.

The research methods presented in this article and the results obtained are appropriate not only for the internal transport systems of basic open-cast mining machines, but they can also be useful for assessing acoustic hazards in other extensive transport systems using belt conveyors with a high capacity and high installed power used (among other applications) in mining, reloading ports, and bulk material storage yards.

2. RESEARCH PROBLEM AND METHOD

As stated in Polish standards and recommendations of European Union (PN-86/M-47015 "Earth-moving machinery for construction purposes. Permissible noise level at operator's station and test methods" and ECC/86/662 Code among others), the equivalent continuous A-weighted sound level for eight hours of exposure should not exceed 85 dB(A).

Large heavy-duty machines used for surface mining (e.g., bucket wheel and bucket chain excavator and stacker) are operated in the so-called "24/7" system and exhibit very high efficiency, which is unattainable for other machinery with a cyclic operation (e.g., front loaders). Nevertheless, high drive power units (up to several hundred kilowatts) must be installed in these machines to achieve such high efficiency. High power drive units cause high noise levels, which create significant acoustic hazards. These hazards can influence the area surrounding those units and can impact a more distant range beyond the open-cast mine. In the past people working in the mine were affected. As inhabited areas came closer to mines, the people living in those places became similarly influenced. This problem is especially significant during nights when these people are disturbed [6, 32, 34].

Therefore, the acoustic microclimate in the surroundings of large basic machines used for surface mining should be studied. Particular consideration should be given to so-called "hot spots" of noise (i.e., areas with the highest levels of sound).

Many works have evaluated the noise level in the industry [1, 4, 9, 10, 12, 14, 15 27, 31, 39-41]. A typical methodology is based on measurements of noise level and evaluations of selected parameters. This is a common procedure when assessing the technical condition and noise hazards.

The starting point for this research was to consider that, in real operating conditions, the noise level – for example, in the excavator zone—is not a deterministic value but a random variable with a specific statistical distribution. This fact should be taken into account when assessing acoustic hazards.

The acoustic climate and acoustic hazards were assessed in the classical deterministic approach, as well as in the probabilistic approach proposed by the authors. In deterministic terms, the so-called equivalent continuous A-weighted sound level for eight hours of exposure was used as the basis for the assessment of the acoustic climate. This is a fundamentally different and reliable approach to the assessment of the acoustic climate (especially to the assessment of the level of noise hazards), as it takes into account the actual operating conditions (random variable of the noise level). The proposed probabilistic noise assessment approach can be used in other working machines and transport systems that operate under various operating conditions.

The present research clearly shows that the deterministic approach to noise assessment yields underestimations (higher values of the permissible time of noise exposure) in relation to the results obtained when taking into account the random nature of the noise level.

The noise level produced by heavy-duty machines is usually treated as a deterministic variable. The relevant recommended occupational exposure limits of noise level are defined in proper international standards (e.g., ISO R 1996). In accordance with these guidelines, the noise level in the tested zones should not exceed the total value of L_{Aeq} = 85 dB(A).

A more detailed assessment of acoustic microclimate, according to the recommendation ISO R 1996, is given by the sound 1/1 octave spectrum and the so-called Noise Rating Curve NR80. If the total noise level exceeds L_{Aeq} = 85 dB(A), then the permissible exposure time t_x (in minutes) to noise can be determined by the following equation:

$$L_{Ax} = 85 + 10 \cdot \log \frac{480}{t_x} \tag{2}$$

where L_{Ax} is the total value of noise (in dB) occurring in a given zone.

However, such a deterministic approach is justified when the noise level is constant or, at most, it is only slightly changeable.

In reality, the noise levels in the zones of the inner transport system of bucket wheel excavators are random variables, which is why noise hazards should be assessed in a probabilistic approach.

Taking this into account, the relevant histograms of the sound level for each "hot spot" of noise should be determined, and the basic parameters of statistical distributions of noise level have to be estimated. Thus, the numerical values of the statistical distribution parameters of the noise level in the tested zones were estimated using the maximum likelihood method. Then, the congruence of that distribution with experimental data was verified using the chi-squared goodness-of-fit test. After that, the authors' conception was proposed to use the quantile $Q_{0.95}$ of random noise level (determined at the confidence level = 0.95) as a measure of acoustic microclimate [33, 34]. According to this idea, the permissible exposure time t_{xQ} to noise should be determined using the following equation:

$$Q_{0.95} = 85 + 10 \cdot \log \frac{480}{t_{xQ}} \tag{3}$$

where $Q_{0.95}$ is the quantile (in dB) of noise occurring in a given zone, and *log* is a decimal logarithm.

It was hypothesized that the L_A sound pressure level (as a random variable) can be described with sufficient accuracy by a statistical distribution. Based on the analysis of the measurement results, noise level histograms were determined, the parameters of these statistical distributions were estimated (using the maximum likelihood method), and the conformity of the theoretical distributions with the actual distributions was tested. Next, quantiles of the order of 0.95 were determined, which were used to determine the level of threats and the permissible noise exposure time.

3. RESEARCH OBJECTS

In this article, some research results of one of two similar bucket wheel excavators are presented. Both large machines were imported from Spain to Poland, where they were rebuilt before operation. One of these tested objects is presented in Fig. 1. The test object weighs approximately 2,000 tons (the total weight, including the feeder, is approximately 2,700 tons), its height is approximately 38 m, and its efficiency is 4,600 m^3/h, which qualifies for the size of medium multi-bucket excavators. With such a large mass, the average pressure that the excavator imposes on the ground under the tracks is approximately 77 kPa. For confidentiality reasons, the name and detailed data of this excavator are not given. The most intensive sources of noise located along the inner transport lines in large bucket-wheel excavators (numbers according to Fig. 1) are listed below:

- zone of the bucket wheel (1),
- zone of the belt conveyor and conveyor idlers on excavating boom (2),
- central discharging zone from the belt conveyor (3),
- zone of the drive unit of the inner belt conveyor (4).

The distance between the sources of noise and the measuring points was around 1-2 m, which took into account both recommendations of the standards and the structure of the machine.

The research was carried out when the bucket wheel excavator was mining overburden with some small hard inclusions. The acoustic microclimate and noise hazards in the tested excavator were assessed following a classical deterministic approach and a probabilistic approach according to the authors' method. A digital sound level meter and SVAN 945A analyzer were used as basic measuring apparatuses.

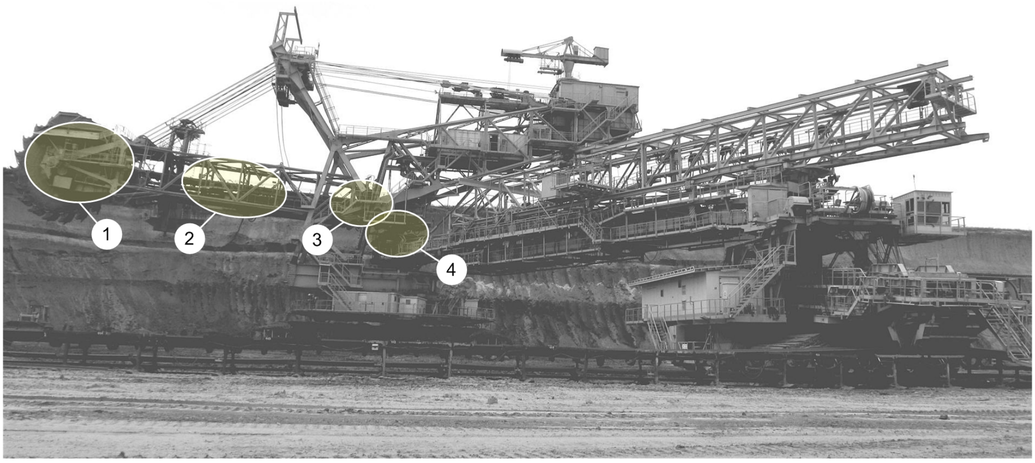

Fig. 1. Research object: a bucket wheel excavator (noise zones are marked)

4. RESEARCH RESULTS

4.1. Zone of the bucket wheel

The bucket wheel is designed to loosen rock from rock and then load and discharge it on the boom-mounted belt conveyor, which is an inner transport system of the excavator. The bucket wheel in the tested excavator has a diameter of D =11.4 m and n = 20 buckets.

The bucket wheel can be treated as a local source of noise where acoustic events are generated by the drive unit, the external forces caused by interactions between buckets and a rock face, and material as it falls into the chute.

4.1.1. Deterministic approach to research results of noise

In this research, the RMS and peak values of sound levels in the left and right sides of the bucket wheel zone were measured. A full real-time octave analysis was also performed. Exemplary results are presented in Fig. 2. Following the deterministic approach to noise, it was found that the mean values of the called A-weighted equivalent sound pressure level L_{Aeq} in the zone of a bucket wheel ranged from 78-85 dB(A). Thus, it follows that, under these conditions, the exposure time to noise should not be reduced to below eight hours. This is an important result because the operator's cab is installed close to the left side of the bucket wheel.

4.1.2. Probabilistic approach to research results of noise

However, the research has shown that the noise level in the zone of a bucket wheel was not a constant variable a random one. The relevant root-mean-square values of sound pressure level varied within the range of 68-99 dB(A) (Fig. 3). Therefore, noise hazards zones should be evaluated using a probabilistic approach.

Taking the above findings into account, relevant histograms of the sound level of the left and right sides of the bucket wheel were determined, and statistical distributions were estimated. The exemplary histogram is presented in Fig. 4. At the same time, it was hypothesized that the randomly varying acoustic pressure level in the tested zones of the excavator's internal transport line can be described by a normal distribution. The numerical values of the statistical distribution parameters of noise level were estimated using the maximum likelihood method, and the fit of these distributions with experimental data was verified using the chi-squared goodness-of-fit test.

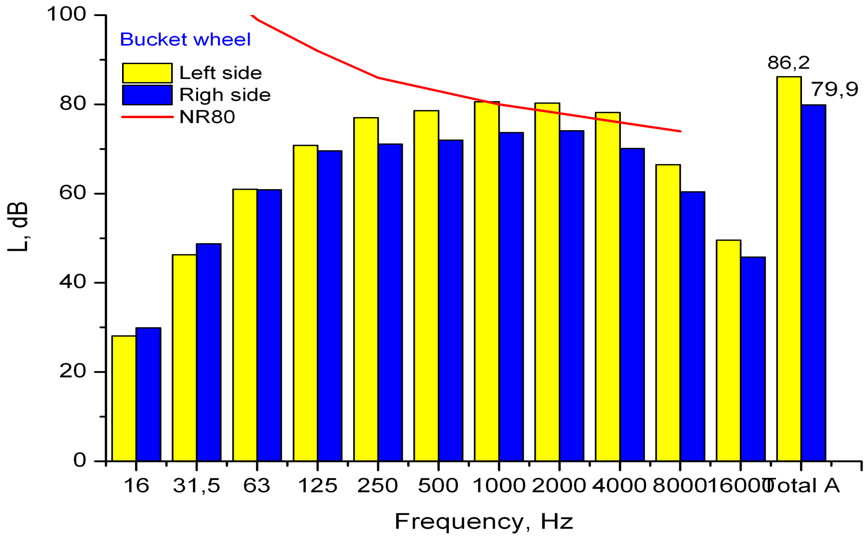

Fig. 2. Noise spectrum on the left and right sides of the zone of the bucket wheel (the relevant Noise Rating Curve NR80 is marked)

On this basis, the quantiles $Q_{0.95}$ are evaluated as follows:

$$Q_{L0.95} = 90.0\ \text{dB(A)}\ ;\ Q_{R0.95} = 84.1\ \text{dB(A)} \tag{4}$$

where Q_L, Q_R – quantiles for the left and right sides, respectively.

Based on these evaluations, the value of the permissible exposure time t_{xQ} to noise (when the sound level is treated as a random quantity) for the left side of a zone of the bucket wheel was estimated as follows:

$$t_{xQ} \cong 152\ \text{min} \tag{5}$$

4.2. Zone of the belt conveyor

The belt conveyor creates an inner transport system designed to take over material from the bucket wheel and move it to the main discharging zone, where the material is transferred to the next transport system, which takes material away from the excavator. In contrast to the bucket wheel, the boom-installed conveyor in the tested excavator should be treated as a continuously distributed source of noise where acoustic events are generated by moving conveyor belts and rotating rollers.

4.2.1. Deterministic approach to research results of noise

In the research, the RMS and peak values of sound level in the left and right sides of the conveyor installed on a boom were measured, and a full real-time octave analysis was performed. Exemplary results are presented in Fig. 5.

The analysis of relevant research results shows that the mean values of total sound level were around 83-85 dB(A). The value of 85 dB(A) was not exceeded, which is generally considered a permissible level for a nominal eight-hour exposure period in workplaces. This finding indicates that there were no acoustic hazards in the zone of the belt conveyor when the deterministic approach was used.

4.2.2. Probabilistic approach to the research results of noise

Similarly, as in the case of the bucket wheel zone, it has been considered that the noise in the zone of the conveyor line was a random variable. Thus, the relevant histograms of the sound level for the left and right sides of a belt conveyor were determined, and the statistical distributions were estimated.

The quantiles $Q_{0.95}$ were evaluated as follows:

$$Q_{L0.95} = 86.2 \text{ dB(A)} \ ; \ Q_{R0.95} = 88.7 \text{ dB(A)} \tag{6}$$

where Q_L, Q_R – quantiles for the left and right sides, respectively.

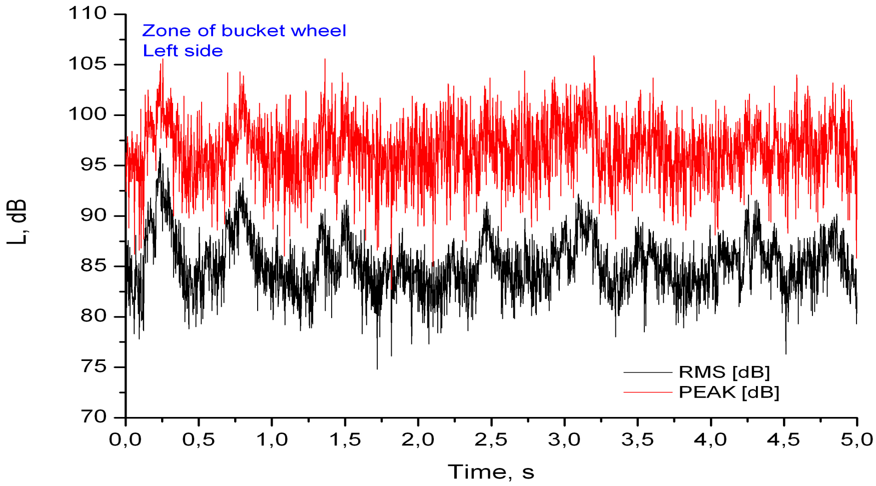

Fig. 3. RMS and peak values of sound level at the left side of bucket wheel zone

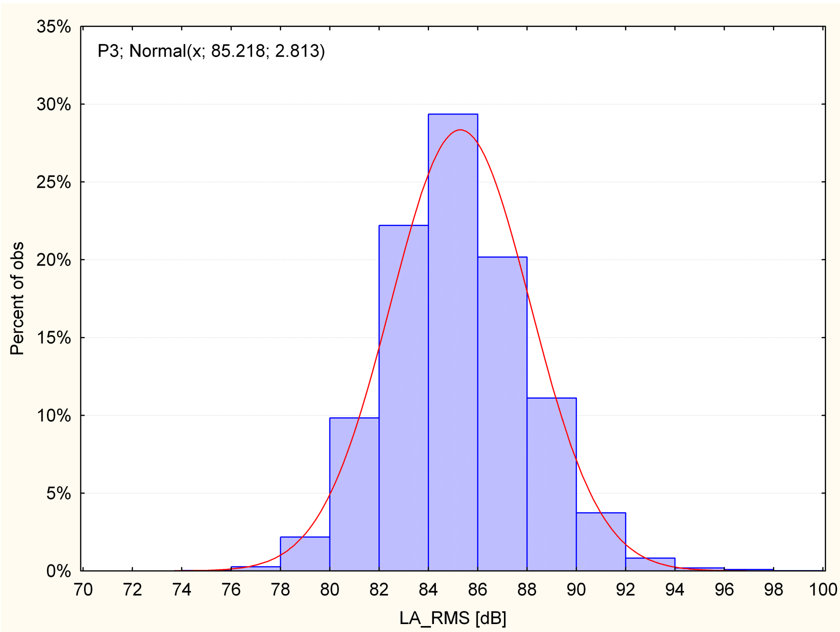

Fig. 4. Histogram of the RMS values of sound level (LA) at the left side of the bucket wheel zone

Based on this evaluation, the value of the permissible exposure time t_{xQ} to noise (when the sound level was treated as random) for the left side of a zone of the belt conveyor was estimated as follows:

$$t_{xQ} \cong 205 \div 365 \text{ min} \tag{7}$$

4.3. Zone of the conveyor drive unit

The belt conveyor in the tested bucket wheel excavator was driven by two similar units (each of which included an electric motor and gearbox) installed on the left and right sides. The acoustic microclimate was assessed when the tested excavator was used for mining overburden with nominal performance.

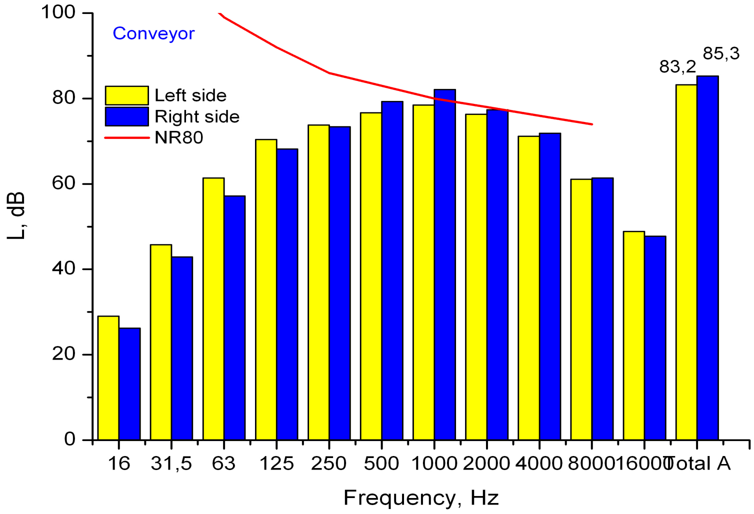

Fig. 5. Noise spectrum in the zone of belt conveyor on a boom on the left and right sides (the relevant Noise Rating Curve NR80 is marked)

4.3.1. Deterministic approach to the research results of noise

The RMS and peak values of sound levels in the left and right sides of the zone of drive units were measured, and a full real-time octave analysis was performed. The analysis of the research results shows that the mean values of total sound level in the zone of drive units of this conveyor were around 93-99 dB(A). The permissible value of 85 dB(A) was exceeded, indicating the presence of noise hazards in the zone of drive units of the conveyor when the deterministic approach to noise evaluation was used. The permissible exposure time t_x to noise (when the sound level is treated as a deterministic quantity) for the left side of the zone of the belt conveyor was estimated as follows:

$$t_x \cong 18 \div 68 \text{ min} \tag{8}$$

The noise spectrum in the zone of the drive unit of the belt conveyor is shown in Figure 5.

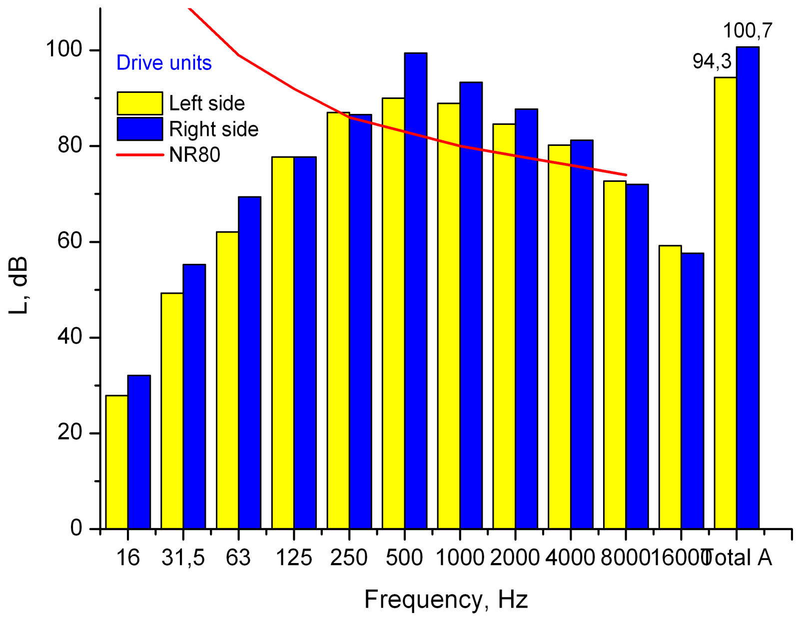

Fig. 6. Noise spectrum in the zone of the drive unit of belt conveyor on the left and right sides (the relevant Noise Rating curve NR80 is marked)

4.3.2. Probabilistic approach to the research results of noise

As in the case of the bucket wheel zone, the noise in the zone of the conveyor line has been considered as a random variable. Because the noise level in the zone of drive units of the belt conveyor was a random variable, the relevant histograms of sound level for the left and right sides of this zone were determined, and the statistical distributions were estimated.

The quantiles $Q_{0.95}$ were evaluated as follows:

$$Q_{L0.95} = 97.6 \text{ dB(A)} \ ; \ Q_{R0.95} = 105.0 \text{ dB(A)} \tag{9}$$

where Q_L, Q_R – quantiles for the left and right sides, respectively.

Based on this evaluation, the value of the permissible exposure time t_{xQ} to noise (when the sound level is treated as a random quantity) for the left side of the zone of the belt conveyor was estimated as follows:

$$t_{xQ} = 5 \div 26 \text{ min} \tag{10}$$

4.4. Central discharging zone

The main discharging zone was created by the dumping hopper, where the material falls from a boom-mounted conveyor and is sent to the next conveyor system. This zone is generally one of the most intensive sources of noise in bucket wheel excavators.

4.4.1. Deterministic approach to research results of noise

The RMS and peak values of the sound level in the main discharging zone were measured, and a full real-time octave analysis was performed. The exemplary results are presented in Fig. 7. The results show that the mean value of the total sound level in this zone was around 90-93 dB(A). The permissible value of 85 dB(A) was exceeded, and thus, noise hazards were indicated when the deterministic approach to noise evaluation was applied. The permissible exposure time t_x to noise (when the sound level is treated as a deterministic quantity) for the left side of a zone of the belt conveyor was estimated as follows:

$$t_x \cong 107 \text{ min} \tag{11}$$

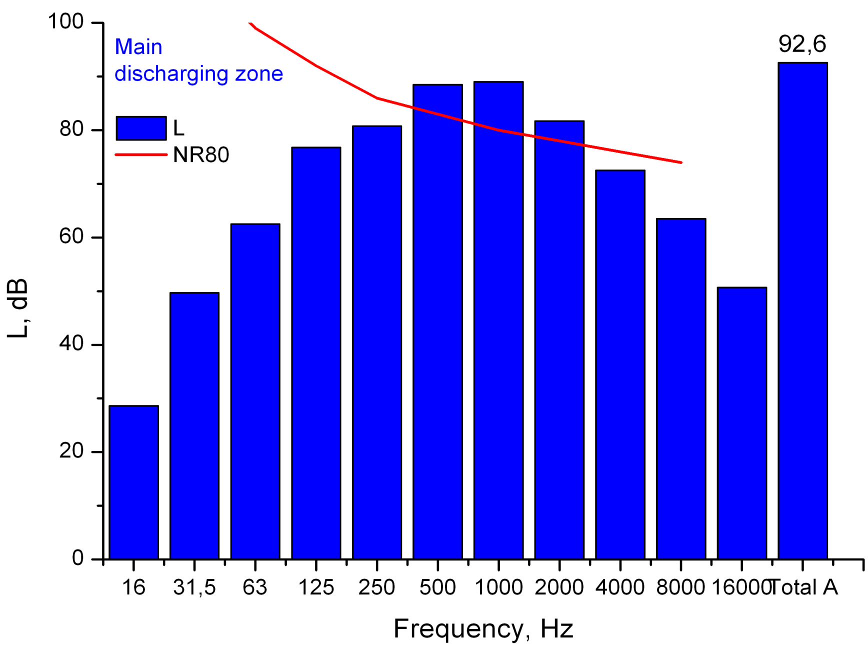

Fig. 7. Noise spectrum in the main discharging zone (the relevant Noise Rating Curve NR80 is marked)

4.4.2. Probabilistic approach to research results of noise

It was taken into consideration that the noise in the main discharging zone was a random variable. The relevant histograms of sound level for the left and right sides of this zone were determined, and the statistical distributions were estimated. In turn, the quantiles $Q_{0.95}$ were evaluated as follows:

$$Q_{0.95} = 96.5 \text{ dB(A)} \tag{12}$$

Based on this evaluation, the value of the permissible exposure time t_{xQ} to noise (when the sound level is treated as a random quantity) for the left side of the zone of the belt conveyor was estimated as follows:

$$t_{xQ} \cong 34 \text{ min} \tag{13}$$

5. ASSESSMENT OF THE ACOUSTIC MICROCLIMATE

The relevant main statistical characteristics of acoustic microclimate in the “hot spots” of noise in the tested bucket wheel excavator are presented in Tab. 1. Based on these characteristics, the values of the permissible exposure time t_x to noise treated as a random quantity were estimated and presented in Tab. 2.

Table 1

Basic statistical characteristics of the noise level in the tested zones

Basic characteristics, dB(A)	Signal	Zone						
		Bucket wheel		Conveyor line		Conveyor drive unit		Main discharging
		left side	right side	left side	right side	left side	right side	right side
Mean value	RMS	85.2	78.7	82.5	84.6	93.5	99.3	91.5
	Peak	96.9	93.6	95.1	94.8	103.7	108.7	101.7
Median	RMS	85.1	78.5	82.6	84.6	93.7	99.4	91.6
	Peak	97.0	93.8	95.2	95.0	104.0	108.9	101.9
Minimum	RMS	74,8	68,4	72,7	75,4	82,6	85,2	75,5
	Peak	82,7	76,3	82,6	83,0	92,3	93,6	85,5
Maximum	RMS	98.6	92.0	92.1	93.8	101.0	110.6	101.1
	Peak	109.2	106.5	105.3	103.8	111.4	119.0	112.0
Quantile $Q_{0.95}$	RMS	90.0	84.1	86.2	88.7	97.6	105.0	96.5
	Peak	102.1	99.9	100.6	99.3	108.1	114.1	106.8

Table 2

Permissible exposure time to noise in the tested zones
(exposure time is expressed and rounded off to full minutes)

Approach	Zone						
	Bucket wheel		Conveyor line		Conveyor drive unit		Main discharging
	left side	right side	left side	right side	left side	right side	right side
Deterministic	480*	480*	480*	480*	68	18	107
Probabilistic	152	480*	365	205	26	5	34
* – there are no noise hazards							

5.1. Summary of the classical deterministic approach to noise

A classical deterministic approach to noise was followed based on the so-called A-weighted equivalent sound pressure level L_{Aeq} (determined for a nominal eight-hour exposure period). This permissible value is recommended as L_{Aeq} = 85 dB(A) for the workplaces in the industry.

Taking this value into account, the following conclusions are formulated:

- In the zone of the bucket wheel, there are no noise hazards.
- In the zone along the belt conveyor, there are no noise hazards.
- In the zone of both drive units of the conveyor, there are noise hazards, and exposure time to noise should be limited to t_x = 19-76 mins.
- In the main discharging zone, there are noise hazards, and exposure time to noise should be limited to t_x = 75-150 mins.

5.2. Summary of the probabilistic approach to noise

A probabilistic approach to noise, according to the authors' concept, takes into account that in real conditions, the noise emitted by sound sources is changeable and random. This idea is based on the so-called quantile $Q_{0.95}$ of random noise (determined at the confidence level = 0.95), which is assumed to measure the acoustic microclimate.

Therefore, the following conclusions are formulated:

- In the zone of the bucket wheel, there are medium-to-high noise hazards, and exposure time to noise should be limited to t_{xQ} = 94-97 mins.
- In the zone along the belt conveyor, there are small-to-high noise hazards, and exposure time to noise should be limited to t_{xQ} = 200-364 mins.
- In the zone of both drive units of the conveyor, there are high noise hazards, and exposure time to noise should be limited to t_{xQ} = 19-76 mins
- In the main discharging zone, there are high noise hazards, and exposure time to noise should be limited to t_{xQ} = 75-150 mins.

6. CONCLUSIONS

The results of acoustic microclimate in the tested bucket wheel excavator show that the probabilistic approach to noise hazards gives considerably lower values of permissible exposure time than the deterministic approach to noise.

The problems of the acoustic microclimate and noise presented in this article are typical for all large heavy-duty surface mining machines. These machines exhibit very high performance, but high-power drive units used, as well as highly efficient transport systems, have to be installed. These components are sources of excessive noise. Therefore, special focus is required to locate the noisiest zones and assess their acoustic microclimate.

In the authors' opinion, noise hazards should be assessed more properly following the probabilistic approach, which is based on the statistical distribution of sound pressure and when the relevant quantile is assumed as a factor of noise. Additionally, the probabilistic approach to noise, according to the authors' concept, takes into account real conditions in which the tested large heavy-duty machine is operated, further supporting the idea that the probabilistic approach to noise should be used.

The increase in acoustic hazards is a significant symptom of the degradation of machines after long-term use. Ignoring these symptoms can have costly consequences—for example, a fire can start on the conveyor belt if the bearings in the rollers seize.

The research methods presented in this article may be useful for studying acoustic hazards in other extensive transport systems using belt conveyors with high capacities and high installed power in industrial sectors other than the mining sector (e.g., transshipment ports, bulk material storage yards).

The probabilistic noise assessment approach is more reliable than the classical deterministic approach because it takes into account the random nature of the noise level. The tests performed in this study were carried out under real conditions during the operation of the tested excavator (during the cutting of the so-called overburden). The tests were carried out under real operating conditions on an exceptionally large facility in zones located at significant heights (approximately 10-20 m). During these studies, the authors had to consider their own safety.

Further studies on other large machines in Poland are planned to locate acoustic hot spots, create a database of vibroacoustic intensity in these areas, and assess and combat the risks in these areas. In addition, comprehensive acoustic tests are carried out in conjunction with vibration tests, which are used in the ongoing assessment of the technical condition of drive units and conveyors. These tests are intended to facilitate rational operational decisions regarding, for example, renovation, modernization, or the replacement of elements.

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