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SOURCES OF VIBROACOUSTIC HAZARDS IN OPEN-PIT MINES OF MINERAL RAW MATERIALS

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Many sources of vibroacoustic energy manifest themselves in open-pit mines of mineral raw materials. Noise and vibrations are the reasons of occupational diseases and injuries at work. Exploitation of open-pit mines of minerals constitutes hazards not only at workstations but also for the natural environment.

Kinds of noise sources depend on the technology applied in open cast mining. Noise levels often exceed the permissible values. Besides high noise levels, values of vibrations – general and local – which are the highest during processes of mining, loading and transporting are also significant. Among machines and devices used at raw material mining the highest noise is caused by crushers, dumping conveyers, bulldozers etc. Blasting works are the source of short-lived noises however, characterised by high levels of acoustic pressures.

Identification of sources of vibroacoustic hazards occurring in one of the open-pit mine is presented in the paper. The obtained results of measurements of noise levels generated by sources of continuous and impulse noises are also given.

Keywords: vibroacoustic hazards, noise sources, noises in open-pit mines.

1. Introduction

Open pit mines of mineral raw materials are characterised by occurrence of various sources of vibroacoustic energy. Kinds of noise sources depend on the technology applied in an open cast mining. The main technique of material excavation in such mines are blasting works, which are the source of short-lived noises, however characterised by high levels of acoustic pressures. Blasting works cause acoustic waves, which are hazardous for buildings and objects not only located at the mine site but also in some distance from it. They are annoying and harmful for inhabitants as well as for the natural environment.

Apart from short-lived noises also continuous noises are manifesting themselves in the open cast mine. Sources of this kind of noise constitute machines and devices used in the excavation processes, transporting, dumping and crushing of raw materials. The highest noise is caused by crushers, dumping and transporting conveyers, and bulldozers. Noise levels often exceed the permissible values. Besides high noise levels, also vibration values – general and local – are quite significant. They are the highest during processes of mining, loading and transporting of aggregate. The need of more precise determination of acoustic energy sources was prompted by the studies – performed by the authors – on limiting the noise level caused in open cast mining by blasting works [5] and on assessment of occupational risks at work stations in such mines [4].

2. Vibroacoustic energy sources

Each machine, device or means of transportation has many elementary vibroacoustic energy sources. The vibroacoustic energy source is understood as a mechanical or acoustic system generating acoustic vibrations. Properties of such source can be assessed in two ways:

- considering the properties of an acoustic field generated by the source, which provide the so-called external or field characteristics of the source,
- considering the properties of the source itself as the vibroacoustic energy emitter.

The collection of such properties constitutes the so-called internal characteristics of the source.

External characteristics of the source are used for assessment of an acoustic effect generated by the source, while internal characteristics – for assessment of the source itself [7].

Sources can be classified from many points of view. The basic division consists of: theoretical models of radiation, physical reasons of noise generation and the noise origin. The detailed description of vibroacoustic energy sources can be found in reference [1].

Classification of vibroacoustic energy sources occuring in open cast mines of mineral raw materials, performed when taking into account two criteria: physical causes of noise generation and the noise origin – is given in Fig. 1. The most representative sources were selected for the presentation. The machines which emit most vibroacoustic energy: are mining machines, especially: crushers, pneumatic hammers, drilling rigs, excavators, dumping conveyers and belt conveyers. The most annoying sources of vibroacoustic energy are explosions at blasting works, which are also the sources of short-lived noises.

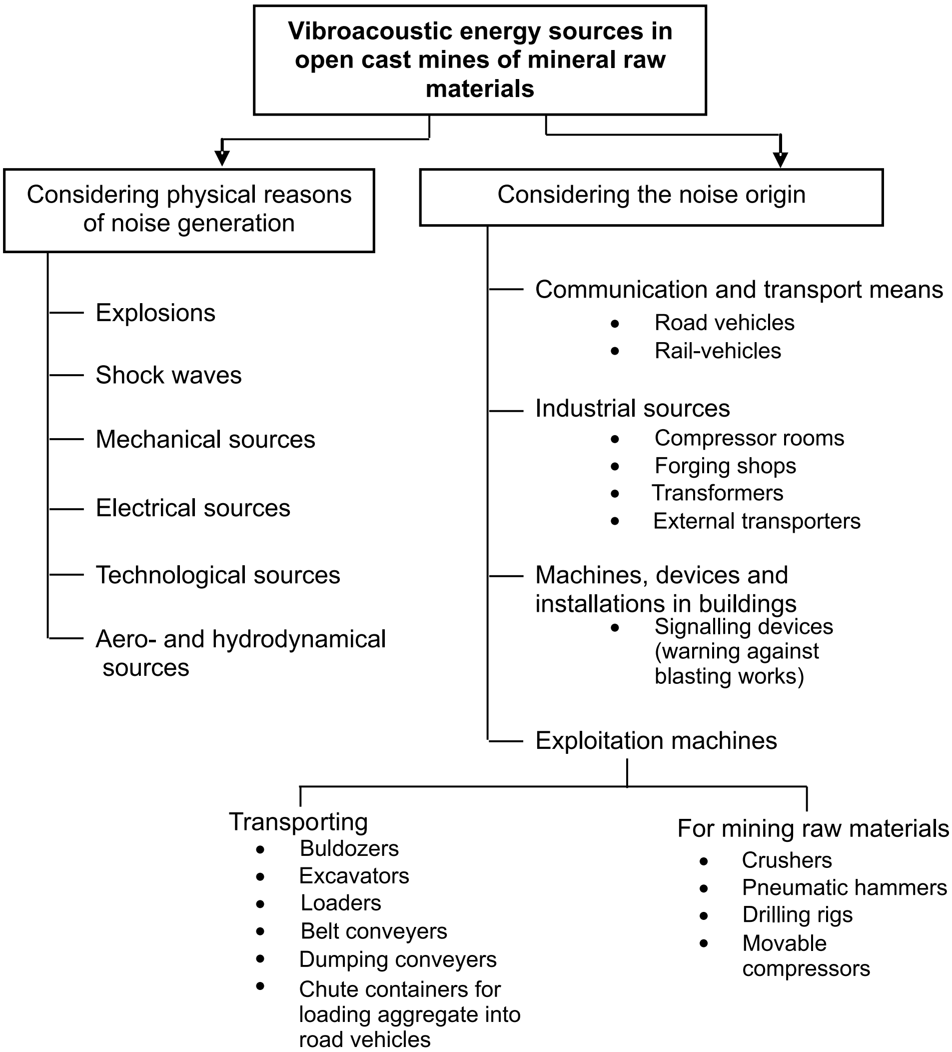

Fig. 1. Classification of vibroacoustic energy sources.

3. Investigations of sources of continuous noises emitted by machines and devices in the andesite mine

Acoustic investigations of sources of continuous noises emitted by machines and exploitation devices were performed in the andesite mine shown in Fig. 2.

Raw material exploitation is being done by an open-pit method in a long-wall system. Explosive materials are used for mining the deposit. Excavated material gathered after blasting near walls is loaded on road vehicles and transported directly to the crusher No I (precrusher) and then – by belt conveyers – to other crushers (Fig. 3) or to the storage spaces.

Fig. 2. Andesite mine.

Machines and devices operate in open spaces and in many cases are not equipped with vibroacoustic supressors. Measuring points are marked in Fig. 3.

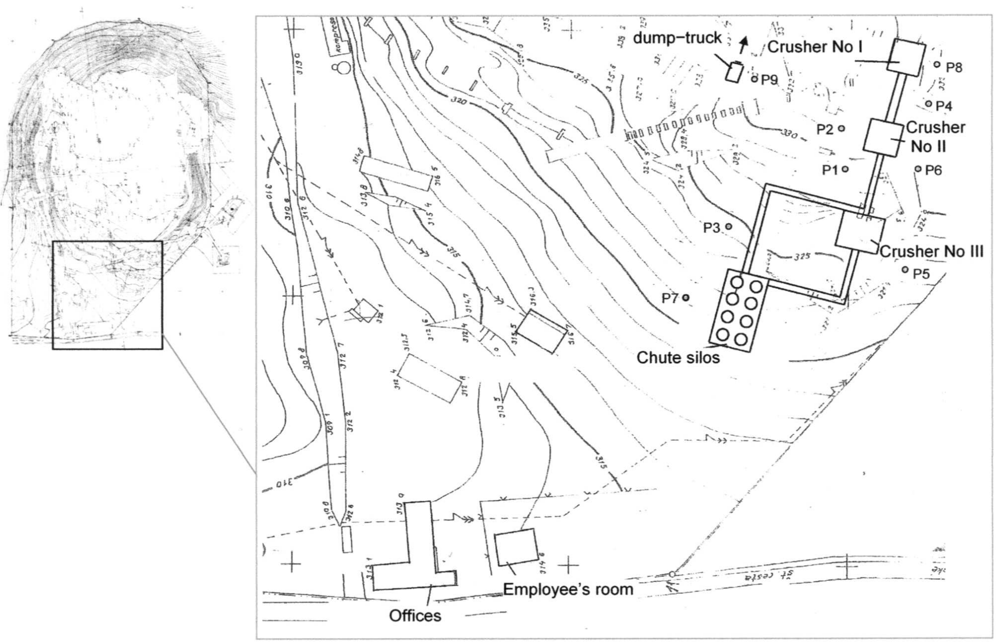

Fig. 3. Arrangement of measuring points for the determination of continuous noises in the andesite mine.

Equivalent sound A level were recorded (Table 1). Analysis was performed in one-third-octave frequency bands. For each measuring point shown in Fig. 3 the sound power level was calculated by using rough method according to PN-EN ISO 3746 standard [8]. As can be seen from Table 1 the sources under test have the power level above 100 dB. The highest sound power level was generated by crushers No II and III

Table 1. Results of measurements of sound power levels emitted by machines and mining devices in the andesite mine.

Measuring point	Characteristics of machine operations	Equivalent sound A level, dB	Sound power level, dB		
		L_{Aeq}	$L_{p(\mathrm{A})}$	$L_{p(\mathrm{LIN})}$	$L_{p(\mathrm{C})}$
1a	Belt conveyer without a feed	69.1	103.1	108.4	107.6
1b	Belt conveyer with a feed	80.0	114.0	117.4	116.7
2	Crusher No II with a feed	92.2	123.7	124.1	123.6
3	Belt conveyer with a feed	80.2	113.0	117.5	114.7
4	Belt conveyer and crushers No I and II with a feed	92.9	125.7	126.3	125.7
5	Belt conveyer and crusher No III with a feed	89.0	121.8	124.3	123.0
6	Belt conveyer and crusher No II with a feed	90.9	125.4	126.7	126.1
7	Chute containers	76.2	112.1	116.4	115.4
8a	Crusher No I together with unloading aggregate from a truck	90.0	112.0	114.3	113.7
8b	Crusher No I	87.4	109.4	112.8	112.3
9a	Empty truck passing; measurement done at a distance of 5 m from a truck	84.2	106.2	112.2	111.7
9b	Loaded truck passing; measurement done at a distance of 5 m from a truck	93.7	115.7	122.0	121.7

together when their operation was accompanied by belt conveyers transporting excavated materials.

Sound power spectra in one-third-octave bands of the selected sound sources – which are characterised in Table 1 – are shown in Figs. 4–7. It can be noticed, that the operation of machines under testing generates approximately constant values of acoustic power level in the frequency range from 20 Hz to 2000 Hz. The power level for higher frequencies deacreases.

Figure 4 presents the comparison of sound power levels for the empty belt conveyer and conveyer transporting the feed (measuring point 1). When the belt conveyer is transporting the feed its sound power level $L_{p(\mathrm{A})}$ is approximately 10 dB higher than when the conveyer is operating but not transporting anything. Such dependency can be observed (Fig. 4) for frequencies above 200 Hz.

Figure 5 presents levels of sound power for the process of aggregate loading on trucks from storage chute silos. The sound power level of this source is constant (equals approximately 110 dB) in the frequency range from 20 Hz to 2000 Hz.

A comparison of sound power level of a loaded truck and an empty truck passing – is given in Fig. 6. The difference of the sound power level is in such case equal approximately 10 dB.

Figure 7 presents the comparison of the sound power level when the crusher No. I is operating alone and when its operation is accompanied by loading with stones from the dump-truck. An increase of an acoustic power level is in this case quite small, equalling approximately 3 dB.

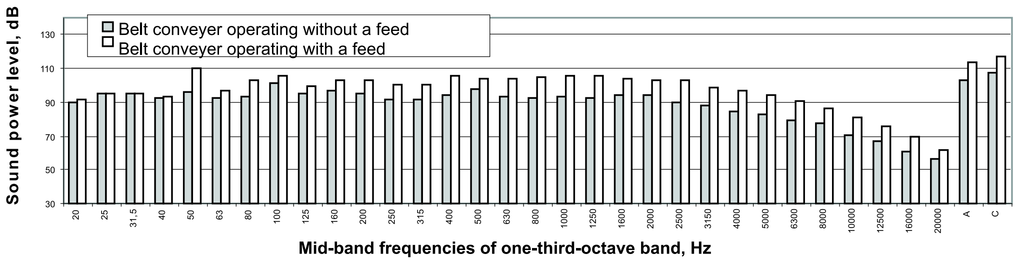

Fig. 4. Comparison of the sound power level in one-third-octave bands for the belt conveyer without and with a feed (measuring point 1).

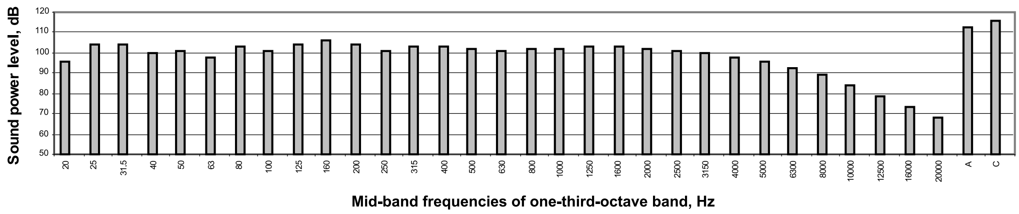

Fig. 5. Sound power level in one-third-octave bands in the process of loading aggregate from a storage chute silos into trucks (measuring point 7).

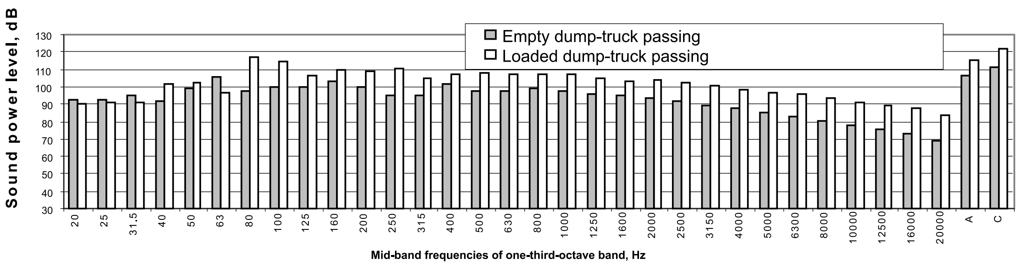

Fig. 6. Comparison of the sound power level in one-third-octave bands when an empty dump-truck and a loaded one is passing (measuring point 9).

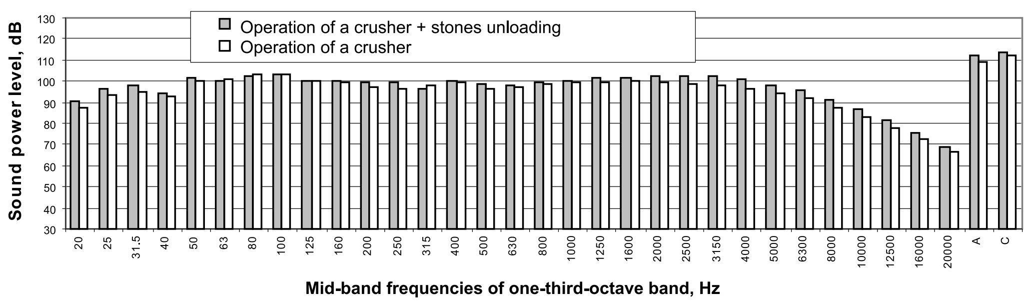

Fig. 7. Comparison of the sound power level in one-third-octave bands when only the crusher No I operates and when it operates and simultaneously stones are unloaded from a dump-truck (measuring point 8).

The obtained results of sound power levels generated by operations of selected machines and devices in the andesite mine will be helpful at the model development of this type of sound sources, which is be the topic of the next stage of studies.

4. Investigations of continuous noises emitted by machines and devices in open-pit mines

There are many sources of continuous noises in open-pit mines of raw mineral materials [2–4]. Measurement results of the acoustic pressure level of noises emitted by individual machines and devices in the tested open-pit mines are collected in Table 2.

Table 2. Levels of sounds emitted by selected machines and devices in the andesite (1), limestone (2) and dolomite (3) mine.

Machine or device	Unit	Measurement description. Kind of operation	Sound A level of sound pressure, dB		
			L_{Aeq}	L_{Amax}	L_{Amin}
Precrusher	2	Measurement at a distance of 1 m (Fig. 3)	86.2	90.4	83.0
Precrusher (loading of stones from wagons to the crusher)	2	Measurement at a distance of 2 m	104.4	113.2	81.2
Precrusher	3	Measurement at a distance of 2 m	87.4	91.9	84.3
Drilling rigs (long openings)	1	Measurement at a distance of 10 m	73–77		
Excavators	3	Loading excavated material on a truck, measurement at a distance of 5 m	77.8	88.1	65.3
Buldozers	3	Measurement at a distance of 10 m	80–91		
Narrow-gauge railway	2	Transporting excavated material from the mine to the crusher	88.8	90.4	81.9
Compressors	1	Measurement at a distance of 2 m	100–110		

The highest acoustic pressure levels are characteristic for crushers, especially at a preliminary crushing of excavated materials. High sound levels accompany loading of crushers, which is usually done directly from trucks delivering materials. In the limestone mine a narrow-gauge railway (shown in Fig. 10) has been applied for transporting excavated materials. Stones from wagons are delivered to the crusher by means of dumping conveyer, shown in Fig. 8.

Auxiliary tools at unloading of wagons are pneumatic hammers. Dumping conveyers are characterised by very high noise levels (approximately 100 dB), which is hazardous for health of employees working at such work stands.

Fig. 8. Dumping conveyer feeding the crusher with stones from wagons.

As an example, sound pressures in octave frequency bands for selected machines and devices are shown in Figs. 9–11.

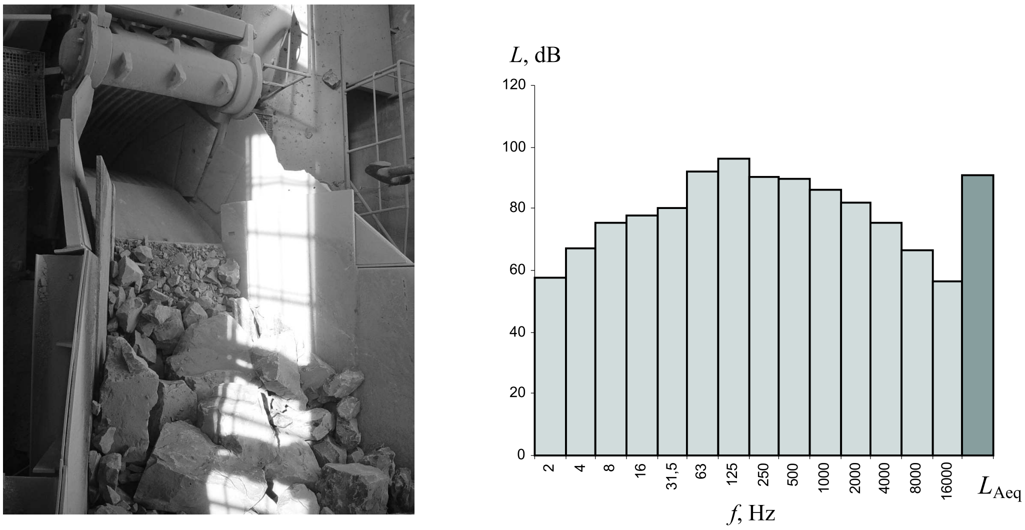

Fig. 9. Sound pressure level in octave bands at a distance of 3 m from the crusher – in the andesite mine.

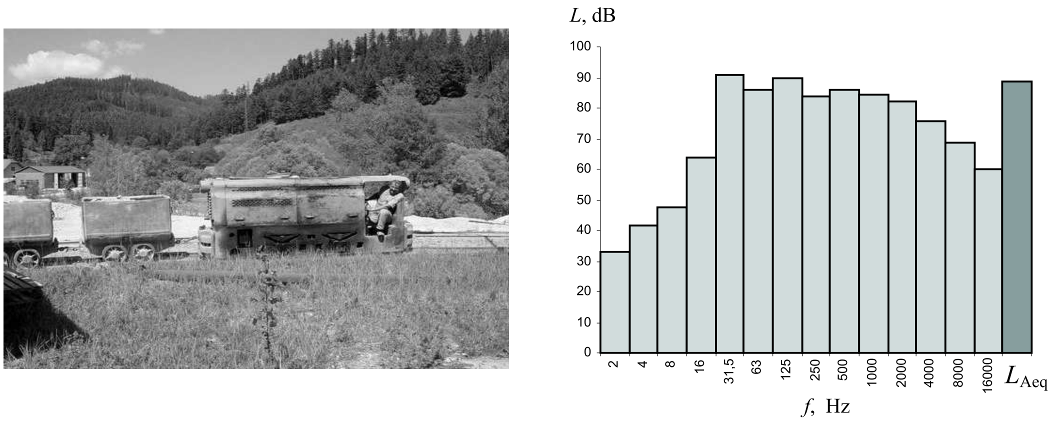

Fig. 10. Sound pressure level in octave bands at a distance of 2 m from the narrow-gauge railway transporting excavated material – in the limestone mine.

Fig. 11. Sound pressure level in octave bands at a distance of 5 m from feeding the excavated material – in the dolomite mine.

Machines and devices operate in open spaces and generally are not equipped with proper vibroacoustic supressors. Assessments of occupational risk at work stations performed by the authors have shown that this risk is very high – even inadmissible – near the most noisy devices such as crushers. Thus, there is a need of developing proper protection measures for employees exposed to noises and vibrations.

5. Sources of impulse noises in open-pit mines

The basic technique of mining in open cast mines of mineral raw materials is the blasting one. Explosions constitute sources of short-lived noises (impulse noises). They are usually accompanied by high levels of sound pressure – 115–140 dB (peak sound pressure level L_{CPEAK}), which are hazardous for the workers, inhabitants of the mine vicinity as well as for buildings. An acoustic pressure level of these type of sources depends on several factors, such as: kind of rock, kind and amount of explosives used, technology and geometrical parameters of blasting works.

The initial stage of investigations of impulse noises generated by blasting works is presented in publication [6]. Impulse noises were investigated in the andesite mine (shown in Fig. 2) and consisted of measuring acoustic pressure levels in two measuring points at a distance of 300 m and 1800 m from the place of detonation. On the basis of measurements of the sound exposure level L_{AE} (according to PN-ISO 1991-1 standard [9]) and calculations of the equivalent sound A level $L_{\mathrm{Aeq(8h)}}$, the approximate distribution of these parameters was suggested. The assessment of hazards generated by blasting works was done both for employees of the mine and for inhabitants of the neighboring village.

In consecutive investigations, which were aimed at the verification of the proposed noise protection measures [5], measurements of sound pressure as well as calculations of the sound energy level (according to [10]) of the explosion treated as a sound source were performed. Parameters characterising the explosion are provided in Table 3.

Table 3. Parameters of blasting works.

Mass of excavated material, ton	Mass of explosive material, ton	Length of opening, m	Number of openings
946.8	150	9	3

Holes for explosive materials were drilled at a distance of 4 m from the wall edge. Measuring microphones were located at a height of 4 m at a distance of 60 m and 80 m from the wall being mined. The obtained results are given in Table 4.

Table 4. Sound levels during explosion – measurement results.

Measuring point	Sound exposure level with A filter, L_{AE}, dB	Equivalent sound A level, L_{Aeq}, dB	Peak sound pressure level, L_{CPEAK}, dB
1 (at a distance of 60 m from the place of explosion)	100.8	88.4	135.5
2 (at a distance of 80 m from the place of explosion)	98.4	86.0	136.1

Sound pressure levels in one-third-octave band for the measuring point located at a distance of 60 m from the place of explosion are shown in Fig. 12. As can be seen, low-frequency components are prevailing in the spectrum.

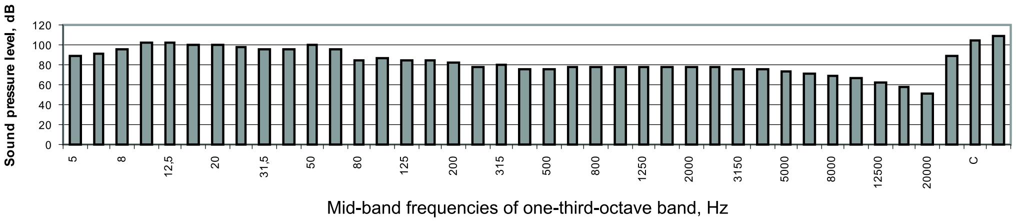

Fig. 12. Sound pressure level in one-third-octave band measured during the explosion (measuring point 1, located 60 m from the place of explosion).

6. Conclusions

The results of the preliminary stage of acoustic investigations of vibroacoustic hazards in open-pit mines are given in the paper. Classification of vibroacoustic energy sources in such mines is presented. Measurements of sound pressure and sound power levels, when typical machines and devices taking part in the technological process – crushers, belt conveyers, chute silos and trucks – are operating, were performed in one of the mines. The determined levels of the acoustic power will be used for model development – with the adequate software – of the acoustic protection of the most important noise sources located in the mine. Characteristics of sources enabled initiation of works on modeling antinoise protections and the selection of the most effective solutions. The author's research concerning assessment of vibroacoustics hazard caused by exploitation of open-pit raw minerals materials as well as limiting noise levels at work stands and the ones generated by blasting works is currently under way.

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