Assessment of the Acoustic Microclimate in the Zone of the Switch Unit in the Heavy Roller Conveyor Line – Case Study

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The sign of the so-called human engineering policy introduced in the industry is decreasing the occupational hazards and making the workplaces as comfortable as possible. That tendency finds expression in the tightened industrial safety-code. Among the annoying /damaging physical factors occurred in the workplace environment, the noise is of especially great importance. One of the most active noise sources in the warehouse systems are the conveyor lines for continuous transport of palletized load units. The measurement results of the main acoustic quantities in the zone of the heavy switch unit in the roller conveyor line are presented. The noise hazards, the speech intelligibility and the perception of the warning acoustic signal in this area are determined.
Keywords: heavy-duty roller conveyors, noise hazards.

1. INTRODUCTION

One of the qualities of the contemporary workplaces is the microclimate created by lighting, atmosphere quality (air cleanness and humidity), temperature as well as noise and vibrations. Each of these above-mentioned factors is considered as an important one and is treated in the regulations properly for a given industrial branch. When the suitable safety rules are not observed, the occupational hazards can occur.

In this context, the disregarded noise is a real danger and can be a source of serious hazards when workers are exposed to noise above a certain level. Then, the excessive noise causes various short-term or long-term health effects to workers and can finally lead to the on-the-job diseases [6]. Taking this into consideration, the human engineering policy is put into practice in most industry branches as a result of the rigorous nationwide on-the-job noise regulations (e.g. [7,8]).

One of the most significant sources of noise in big warehouses are the heavy roller conveyors lines for transport of palletized load units. Because of theirs continuous operation, workers are endangered by long-duration noise what can have a negative influence not only on the human hearing system (inducing the hearing handicap) but also can cause a so-called non-auditory effects: functional and physiological (stress, feeling of discomfort, annoyance, troubles with concentration etc.).

The roller conveyors systems used in warehouses are modular structures which consist of several typical units such as e.g. input and output stations (conveyor track modules), straight modules, branching and junctions units (turntables, transfer cars, turntable-transfer car units). Each of these components can be considered as an individual source of noise. As the conveyors are continuously operated, the exposure time and noise dosage in the neighborhood of the transport line is usually bigger than in other zones of a warehouse.

The additional non-healthy effects of the excessive noise level can make direct verbal communication more difficult (as a result of interference of speech intelligibility) and can increase the danger of jamming of the acoustic warning signals. The reason of these last effect is increasing the natural hearing threshold at a given frequency range induced by on-the-job noise exposure. This is a so-called masking phenomenon when a person, who hears a system, perceives only the louder noise and the quieter sound becomes “imperceptible”.

Taking this into consideration, the noise measurements in the zone of the roller switch unit (Turntable-Transfer Car) in the conveyor line for transportation of heavy unit loads on Euro pallets were carried out. On this basis, the noise hazards, effectiveness of the face-to-face verbal communication and audibility of the warning signal (buzzer) by operation of the roller conveyor line were determined.

2. RESEARCH OBJECT

The measurements were carried out in the zone of the switch unit, composed of the following subassemblies (Fig. 1):

- Straight Driven Roller Conveyor Module
- Turntable-Transfer Car Combined Unit.

installed in the laboratory in the Institute of Machinery Design and Operation (Wroclaw University of Technology).

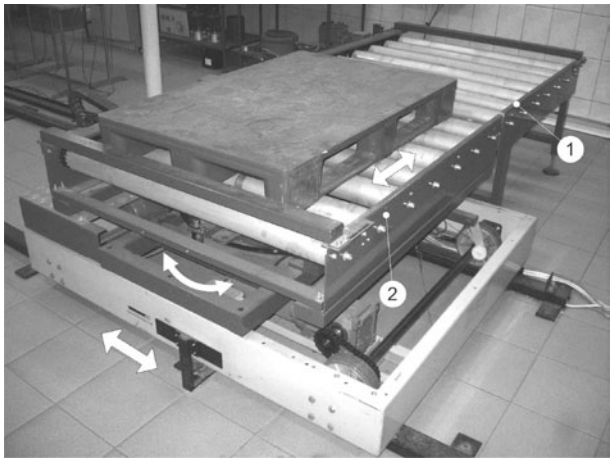

Fig. 1. Research stand: 1- Driven Roller Conveyor Module, 2- Turntable Transfer Car

The following main acoustic quantities of the microclimate in that zone were measured or determined:

- sound pressure p and A-weighted sound pressure level L_A,
- maximal values of A-weighted sound level for the measuring period $L_{A,\max}$,
- peak sound level values $PEAK$
- sound exposure level SEL referred to the integration time equal to one second,
- equivalent sound level $L_{Aeq,T}$ (integrating sound level) related to measuring period,
- octave band noise spectrograms.

The measurements were carried out in the points $P1 \div P9$ (Fig. 2) for the following operation cases of the conveyor line:

- the Driven Roller Conveyor Module and the Turntable-Transfer Car are joined together (measuring points $P1 \div P6$),
- lateral movement of the Turntable-Transfer Car with a unit load on Euro pallet (measuring point $P7$),
- right rotational movement of the Turntable-Transfer Car (measuring point $P8$),
- left rotational movement of the Turntable-Transfer Car (measuring point $P9$).

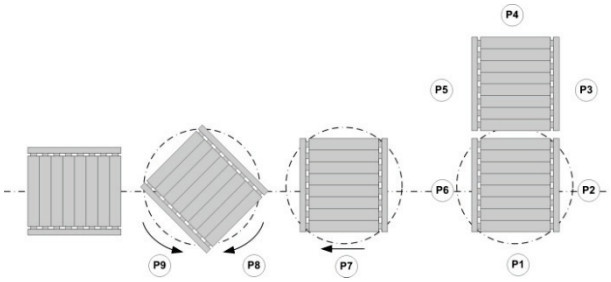

Fig. 2. Location of the measuring point of the noise in the zone of the roller conveyor line

As a measuring instrument the Digital Sound Level Meter type Svan 945A (Svantek) was used with Logger functionality for saving the results in the internal memory of the instrument

3. ANALYSIS OF THE RESEARCH RESULTS

3.1 General evaluation of the acoustic microclimate

3 basic quantities were taken into consideration as a basis of the evaluation of the acoustic conditions in the zone of the switch unit: equivalent sound level $L_{Aeq,T}$, sound exposure level SEL and peak sound level values $PEAK$. Their typical values are shown in Fig. 3.

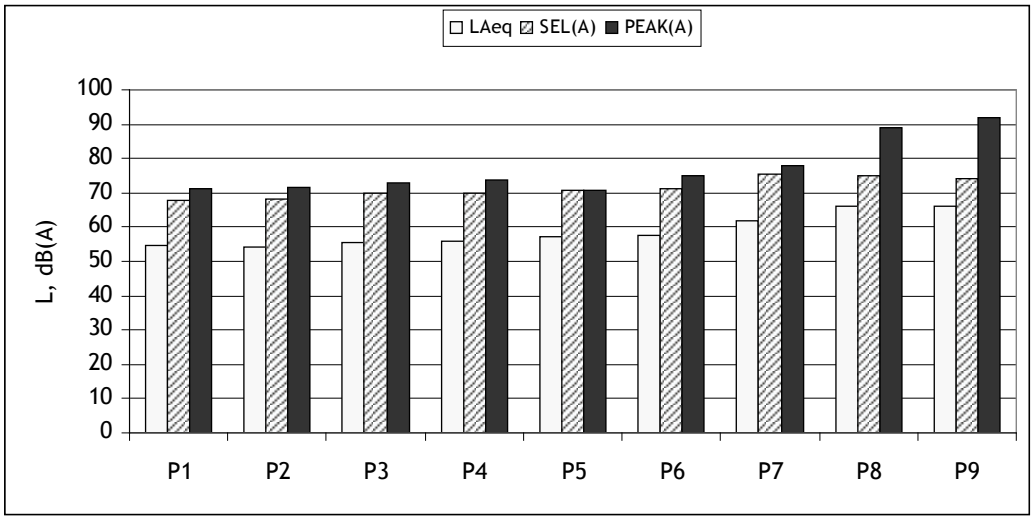

Fig. 3. Typical values of the basic acoustic quantities in the measuring points in the zone of the heavy roller switch unit

The results of the measurements show that when both units: Straight Driven Roller Conveyor Module and Turntable-Transfer Car are joined together and the unit load is transported down the conveyor line, the equivalent noise level L_{Aeq} is nearly the same in the whole surround zone and reach up to $L_{Aeq} = 54 \div 57$ dB(A) where the higher values are relating to the side where the geared motors are installed. However, the noise of the single acoustic events in the roller switch unit, referred to the times of 1 second, is higher and have a level of $SEL = 68 \div 71$ dB(A).

By the left and right rotational movements of the Turntable-Transfer Car the noise is significantly higher, then the peak sound pressure level reaches the values of $PEAK = 90$ dB(A). Workers may feel uncomfortable as a result.

3.2 Evaluation of the noise hazards

The basis of the general evaluation of the noise hazard is usually a so-called equivalent A-weighted sound pressure level $L_{A,8h}$ related to the eight-hour exposure time. According to this criterion, when at an industrial workplace the sound level permanently exceeds the permissible value of 85 dB(A), the noise hazards can take place [7, 8]. However, for the exposure time T shorter than 8 hours, an acceptable sound level is higher and the following formula can determine it (where T is the time expressed in minutes):

$$L_{A,T} = 85 + 10 \log \frac{480}{T} \text{ [dB]} \qquad (1)$$

According to the above-mentioned criterion, the noise hazards do not exist in the zone of the tested heavy roller switch unit because in any measuring points the equivalent sound level L_A is not higher than 85 dB(A) - although the peak values reach 90 dB(A) (s. Fig: 3).

A more detailed evaluation of the acoustic microclimate in the chosen zone of the roller conveyor line was made on the basis of the spectrum analysis of the sound level and by means of so-called Noise Rating Curves *Nx* for Environmental Noise Rating given in ISO R 1996 [1]. The index x of the Noise Rating Curve *Nx* is determined from the approximate formula [1, 2, 5]:

$$Nx \cong L_{Aeq,8h} - 5 \ ; \ [dB] \qquad (2)$$

The rating of noise hazards is the highest exceeding of the suitable Nx-Curve by the values in the octave spectrum of sound. That "overflow" is a basis of determining the maximum exposure time for noise.

According to that the sound level spectra of noise in the zone of the switch unit are determined and compared with some Noise Rating Curves. The respective results are shown in Fig. 4. The sound spectrum of noise emitted when the palletized unit load is transported down the conveyor line does not exceed the Noise Rating Curve *N*55 which approximately corresponds with the equivalent sound level $L_{Aeq,8h} = 60$ dB(A).

Therefore, in the zone of the roller conveyor switch unit the requirements for suitable minimal acoustic comfort at the industrial workplaces in interior spaces – with no significant annoyance caused by noise – are met.

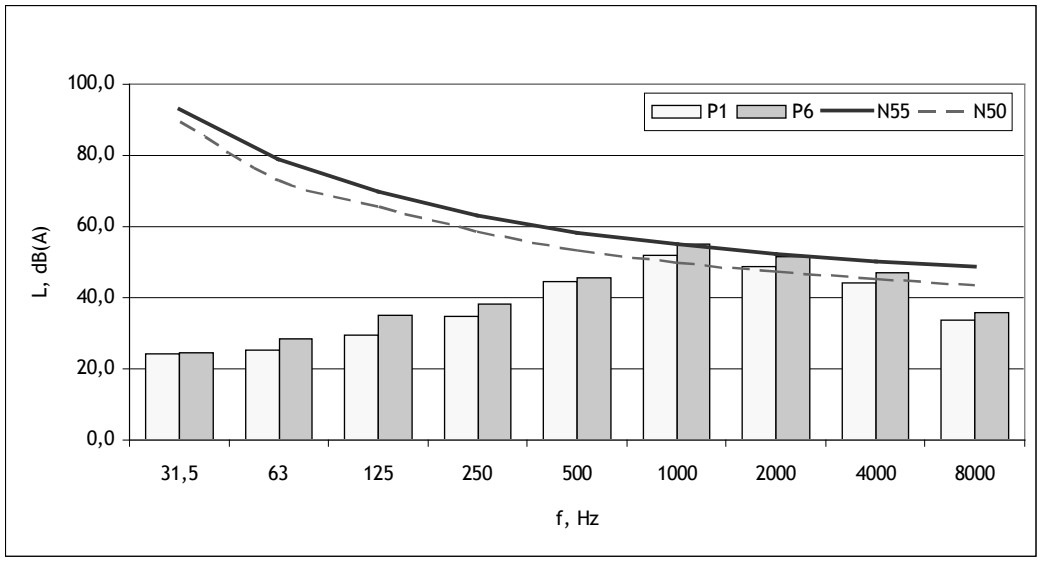

Fig. 4. Typical sound level spectrum of noise in the zone of the heavy roller switch unit and the suitable upper limited noise rating curves N

3.3 Evaluation of the speech interference

Noise emitted in a zone nearby a heavy switch unit of a roller conveyor line can "cover" other lower sounds and make speech difficult to understand. This is a so-called masking phenomenon. In consequence, if noise of the machinery is excessive, any conversation is difficult. That happens especially when noise is high at the frequency range of $f = 4000 \div 6000$ Hz which is usually critical for good understanding of speech [3, 4].

One of the indices for the evaluation of noise influence on speech intelligibility is a so-called speech interference level L_{SIL} [1]. This index is determined as the arithmetic mean from the sound pressure levels in four following octave bands: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Basing on this factor, the required vocal effort (sound level of speech) K by speech communication can be estimated from the following formula [1]:

$$K = L_{SIL} + 20\log r \qquad (2)$$

(where: $r \geq 1{,}0$ m - distance between the interlocutors).

By conversation in a normal voice, the average vocal values are $K_{wom} \cong 50$ dB for women and $K_{men} \cong 54$ dB for men. When the required vocal effort is higher than respectively $K_{wom} \geq 67$ dB or $K_{men} \geq 71$ dB, speech communication is relatively difficult and must be carried on very loudly.

By a face to face communication, upper permissible limit of speech interference level is usually assumed as follows: normal voice $L_{SIL,nv} \cong 50$ dB and raised voice $L_{SIL,rv(\max)} \cong 60 \div 62$ dB.

The arithmetic mean from the sound pressure levels in the above listened octave band in the more noisy measuring point *P*6 is $L_{SIL,P6} = 47 \div 50$ dB(A). Then, a face to face speech communication in the zone of the roller switch unit – when palletized unit loads are transported down the conveyor line – is not possible while speaking with a normal voice. However, by rotational movements of the Turntable-Transfer Car noise is higher and speech interference level is $L_{SIL} = 56 \div 60$ dB(A). In those cases speech communication can be interfered and requires speaking louder.

3.4 Evaluation of audibility of a warning signal

Sonic warning signals used in the transport systems: conveyors and vehicles should have acoustic characteristics suitably adapted to the environmental conditions in the warehouses. Among those features, sound level, spectral structure and directional sonic characteristic are of the special importance.

If a warning sonic signal is to be effectively performed, some basic futures are recommended [5]:

- by a signal of short duration sound level should not exceed the peak values of $L_{PEAK} \leq 105$ dB(A). Otherwise, signal is

perceived as an annoyance or in the extreme cases could be horrifying,

- to avoid a so-called masking effect of the warning signal, its level must be higher by at least $10 \div 20$ dB than the background noise. Otherwise, perception of a signal by human hearing system can be unsuitable or even wrong,
- the sound spectrum of a signal should be at least bitonal (bimodal), where the fist modal value should be in the range of the lower frequencies of $f_{low} = 230 \div 580$ Hz and the second modal value – in the higher frequencies of $f_{high} = 3000 \div 5000$ Hz. Besides, the acoustic spectrum of a signal should be broad-band, which means: it should have as many harmonic components as possible.

The first of the above-mentioned recommendations, with reference to a warning signal in the tested heavy roller switch unit, is met. The peak values are of $L_{PEAK} \cong 72{,}5$ dB(A), therefore they do not exceed the suggested permissible level $L_{PEAK} \leq 105$ dB(A).

The second postulate – to avoid a signal masking – is also satisfied in the cases when a load unit is transported down the conveyor line (without rotational movements of the Turntable-Transfer Car). Then a sound level of the warning signal is by $15 \div 20$ dB higher than the noise generated by the conveyor system (Fig.5). thus, there is no fear of "sound hiding" of a warning signal.

On the contrary, by the rotation of the Turntable-Transfer Car the peak values the noise are comparable to the sound level of the warning signal or even they are higher at some moments (Fig. 6). Thus, in those cases a partial masking phenomenon of acoustic signal occurred.

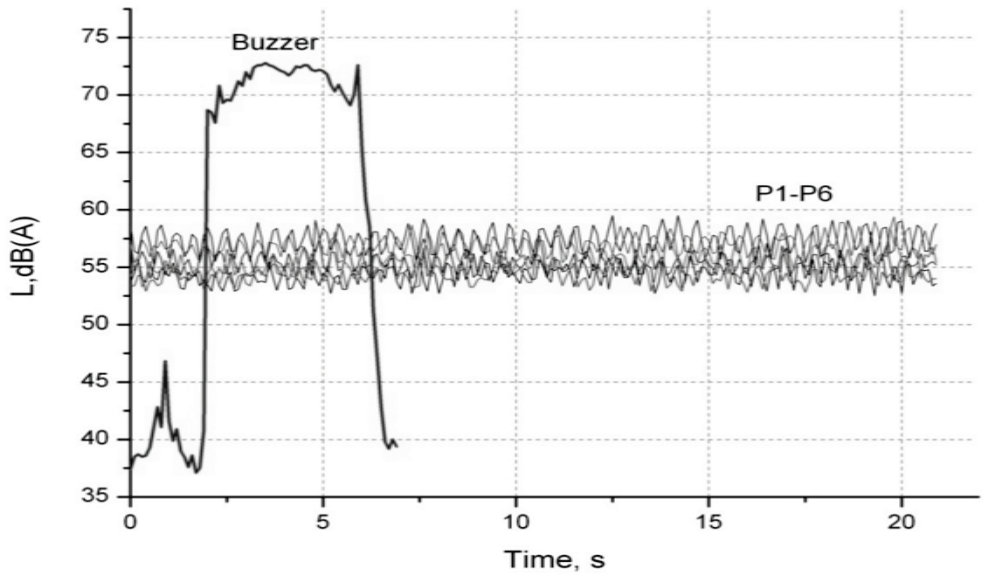

Fig. 5. Sound lever of the warning signal (buzzer) against the background of the noise generated while the unit load is transported along the conveyor line

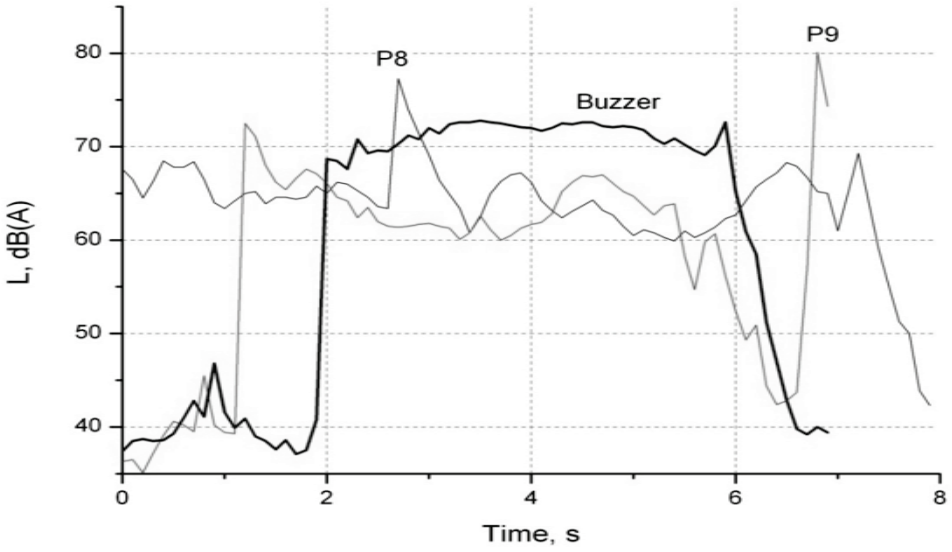

Fig. 6. Sound lever of the warning signal (buzzer) against the background of the noise generated while the roller switch unit is rotated right (P8) and left (P9)

The third recommended future of the warning acoustic signal – to have the bitonal sound spectrum – is as a matter of fact satisfied. The higher modal value is $f_{\mathrm{mod}(2)} \cong 4000\,\mathrm{Hz}$ falls in the suitable range of the frequencies of $f_{high} = 3000 \div 5000\,\mathrm{Hz}$ but the lower modal value of this signal $f_{\mathrm{mod}(1)} \cong 31{,}5\,\mathrm{Hz}$ is out of the suggested frequency range of $f_{low} = 230 \div 580\,\mathrm{Hz}$ and moreover, its level of $L\big|_{f=16\,\mathrm{Hz}} = 25{,}1\,\mathrm{dB(A)}$ is under typical human hearing threshold (Fig. 7).

4. SUMMARY

The measurements of main acoustic quantities of microclimate in the zone of a heavy roller switch unit (Turntable-Transfer combined Car) were carried out. On this basis the following aspects were analyzed:

- noise hazards according to recommendations suitable for industrial workplace,
- speech interference by face to face vocal communication,

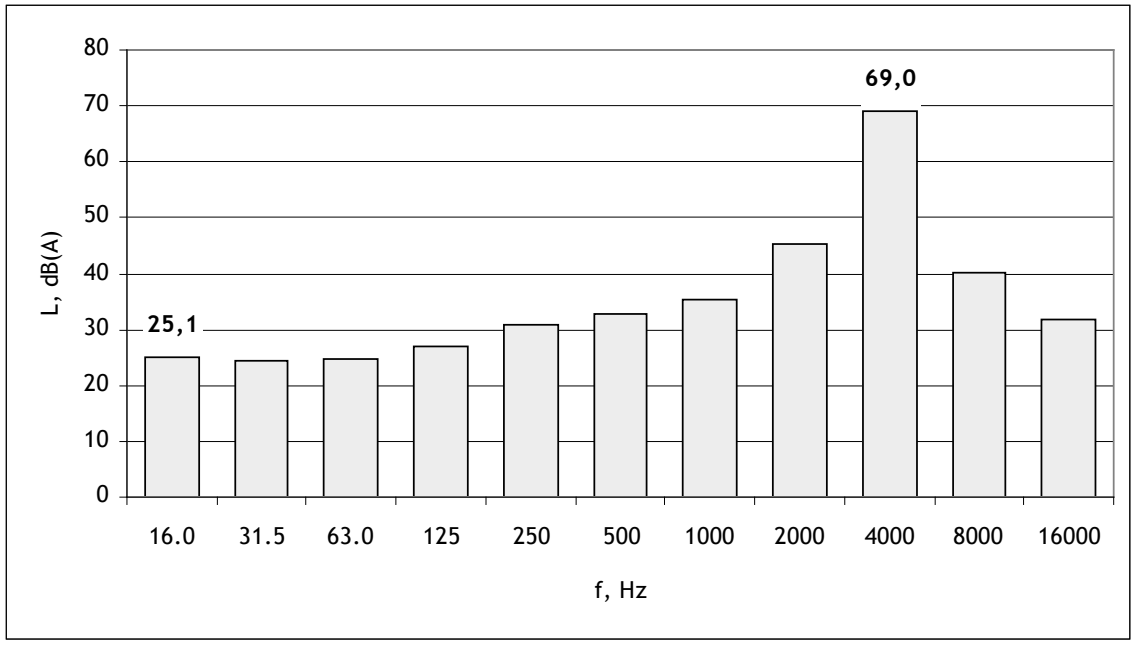

Fig. 7. Acoustic spectrum of the warning signal (buzzer)

- audibility of a sonic warning signal while a heavy roller conveyor line is operated.

Analysis of the research results has shown that there is no noise hazards in the zone of a tested roller switch unit and acoustic conditions are acceptable for the industrial areas with the eight-hour noise exposure time of workers.

However, certain reservations can be formulated about a warning signal, which has too lower sound level and can be masked by a noise generated by rotational movements of the tested heavy roller Turntable-Transfer Car.

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