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SOUND INSULATION OF PLYWOOD TRANSPORTER

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Abstract: *The paper presents a procedure for design of noise protection system for an industrial plywood transporter. It is noticed in exploitation that the transporter occasionally emits high frequency sound, which is detected as a distinct tone at a measurement point in nearby residential area. A technical solution of a light revetment is presented, and its insulation properties are calculated.*

***Key words**: noise, plywood transporter, sound insulation*

1. INTRODUCTION

The paper presents a technical solution of noise protection for a wood chip conveyor at a plywood factory bordering on the urban city area. Machines and equipment that generate high levels of noise are used in the plywood production process. In this case, the dominant sound sources such as fans are sound-isolated [1]. In addition, toward the residential area two sound barrier 6 m high and 110 m long in total were built [2]. Thanks to protection, noise level is significantly reduced. In the current situation, it shows noise coming from some wood chip conveyors with height exceeding the sound barrier height.
For calculation and the insulation in this case a conveyor closest to residential area was selected. The measurement finds that during such conveyor operation mode pulse and tonal properties of the noise appear. On the basis of frequency analysis of noise, and acoustic calculation [4] and possibilities of technical realization, a light acoustic barrier armoring the conveyor along the entire length was selected. The light acoustic barrier should reduce noise emission and, while doing it, not burden the wood chips conveyor structure by its weight.

2. SOURCES OF NOISE

Equipment and machinery used in the production of plywood are a group of stationary sources that generate high levels of noise.
Raw wood chip is delivered by the chain conveyor from silo to the dryer. Chain conveyor for wood chip, which is analyzed in this paper, transports the wood chip from the silo of the raw wood chip to the dryer. It is 19.7 m long. In addition to the aforementioned carriers in a factory, there are several conveyors of similar purpose and noise levels. The dry wood chips conveyor is the closest to residential area, so the level of noise that it generates is a dominant compared to other conveyors.
Chain conveyors at the plant are used to transport dry and raw chip. These conveyors achieve the highest capacity if they are in the horizontal position. They can also transport under deflection, however, their capacity is reduced. In comparison with other conveyors they take up less space and can be used for the transport of various bulk materials. Conveyor bed is made of steel plates with reinforcements of steel profiles, and drive and tensile sprocket wheel are of the wear-resistant cast. Transport is enabled by an endless chain with vanes that while sliding at the bottom of the bed take the material up and carry it in the direction of the drive sprocket wheel. Input and output necks can be placed along the entire length of the conveyor. The drive is provided by an electric motor with reduction gear via chains and sprockets.

Fig. 1. Chain conveyor for raw wood chip

The conveyor chain is lubricated by oil that falling free from the tank placed at the top of the conveyor. If there is a blockage of oil pipelines or shortage of oil, squeaking of a chain is drastically increased. If the conveyor works with reduced capacity or "in neutral", that also leads to the squeaking of a chain and blades.

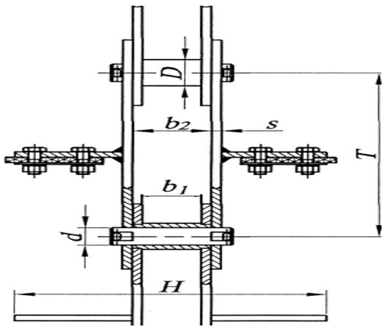


Fig. 2. Chain with blades

2.1 The level of noise at the source

Factory works all day without any interruptions. The conveyor noise levels were measured at a very close distance (up to 0.5 m), in order to eliminate the influence of other sources. As the conveyor bed has a prismatic shape, measuring of noise levels was carried out on all four sides in order to more reliably determine the level of noise emitted by each surface of conveyor (Figure 3).

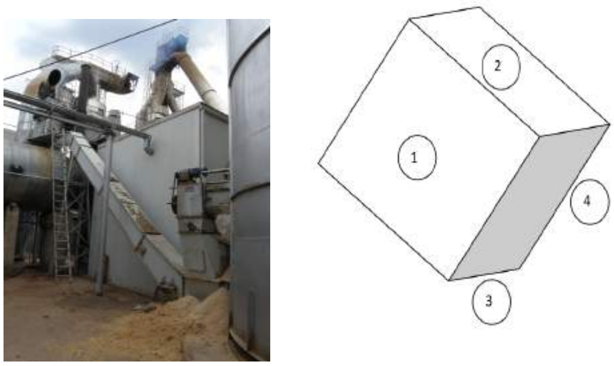


Fig. 3. Conveyor and measuring points in all sides

Measurement of noise levels was carried out in the middle of the conveyor, on the all sides. The reason for such a measurement is because discernible squeaking and beeping of conveyor chain is heard occasionally.

Table 1. Noise levels on all sides of conveyor

Pos.	**L_{Aeq}** [dB(A)]	**L_{AImax}** [dB(A)]	**L_{AFmax}** [dB(A)]	**ΔL_i** [dB(A)]
1	84.3	99.9	97.2	2.7
2	80.5	93.5	89.4	4.1
3	82.2	95.8	93.8	2
4	82.3	97.5	95.0	2.5

Beside the equivalent noise level with A weighting (L_{Aeq}), also the maximum noise levels with the pace of showing IMPULSE and FAST (L_{AImax}; L_{AFmax}).

In order to determine the impulse in noise the measurements were carried out and their results are shown in Table 1. The difference in noise level is determined according to the formula (1) defined by the standard [4]:

$$\Delta L_I = L_{AImax} - L_{AFmax} \left[dB(A) \right] \qquad (1)$$

If the difference **ΔL_I** less than 2 dB, source noise at the measuring point has no impulses.

Difference: L_{AImax} – L_{AFmax} is determined for each individual measurement (Table 1). The measurement results show that the impulse character of the noise is present in all four measuring positions.

2.2 Noise level at the measuring point

Za ocenu buke fabrike u stambenom naselju, odabrano je merno mesto koje se nalazi između dve stambene jedinice (u nivou fasada) na rastojanju od 40 m od transportera. Na osnovu akustičkih proračuna i ranijih merenja [2], [1] , odabrano merno mesto ima najviši nivo buke u stambenoj zoni koja je ugrožena bukom fabrike iverice. U daljim analizama ova merna tačka je označena sa MT_1. Prilikom merenja buke, mikrofon je postavljen na stalak visine 150 cm.

Table 2. Noise levels at measuring point MT_1

Pos.	**L_{Aeq}** [dB(A)]	**L_{AImax}** [dB(A)]	**L_{AFmax}** [dB(A)]	**ΔL_i** [dB(A)]
MT_1	64.7	74.1	71.3	2.8

At the measuring point MT1 measurements of noise levels are performed, and the results are shown in Table 2. According to equation (1) at the measuring point a noise impulse character is determined.

The total equivalent noise level of 65 dB (A) at the measuring point comes from the operation of all plant and machinery in the factory.

$$L_R = L_{Aeq} + K \left[dB(A) \right] \qquad (2)$$

The relevant noise level LR is defined as the sum of A-equivalent noise level and correction of the noise level (K). The correction factor K is defined by standard [5]. This factor includes, among other things, the correction of the noise level for normal impulse noise (KI) of 5 dB. Other correction factors of the noise level in this case have a zero value. In that way a reference level of noise in the measurement point of 70 dB (A) is determined.

Measuring point is located along the regional road, and as such, classified in V acoustic zone [7], with the limit values of noise indicators in the open space of 65 dB (A) for day and evening and 55 dB (A) for the night. The relevant noise level at the measuring point exceeds the limit values of indicators of environmental noise during the referent daytime and night-time.

As the occasional conveyor creaking is clearly recognized at the measuring point, it can be concluded that impulsive character of noise mostly comes from the work of the conveyor.

2.3 Frequency analysis of noise

Beside the measurement of the equivalent noise level on the conveyor itself and at the measuring point in the residential area, the frequency analysis of the noise was carried out, too. At the same measuring points frequency characteristics of noise were measured with 1/3 octave filters. Noise is a wide area type, because there is an approximately even distribution of sound energy in a wider frequency range. Figure 4 presents the 1/3 octave frequency spectrum measured from the front side of the conveyor (item 1), the modes with and without chain creaking.

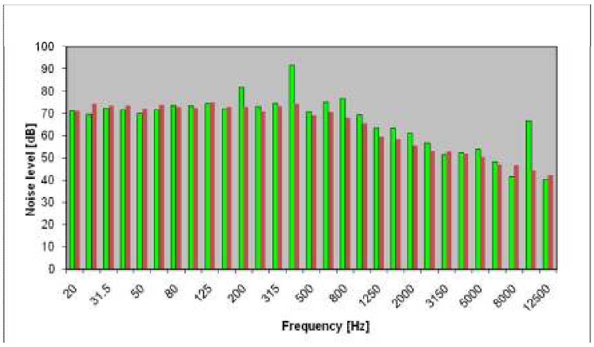


Fig. 4. Frequency analysis of conveyors noise

Figure 4 shows noise level in the frequency range from 20 Hz to 12500 Hz.

The noise is tonal [4], if the difference between the adjacent tierce in the low, mid and high frequencies is higher than:

- 15 dB at the low frequency range (25 Hz - 125 Hz)
- 8 dB at the mid frequency range (160 Hz - 400 Hz)
- 5 dB at the higher frequency range (500 Hz - 10000 Hz)

According to a simplified method for the evaluation of tonality, frequencies that give tonality to noise are shown in Table 3.

Table 3. Frequency with emphasized tone

	Frequency [Hz]			
	200	400	800	10000
Level difference ΔL [dB]	8.7	17.3	8.8	22

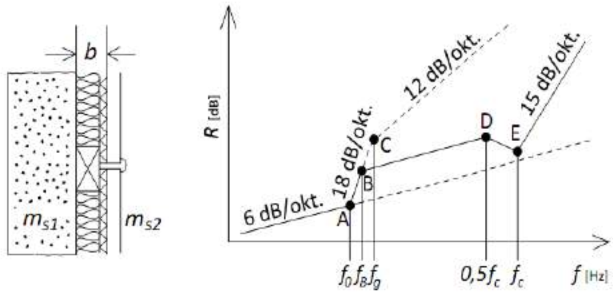
The results of frequency analysis show that the source noise has tonal character, because at frequencies of 200 Hz, 400 Hz, 800 Hz and 10,000 Hz, the difference in noise level between the adjacent tierce exceed the limit values that are defined by a simplified method.

3. TECHNICAL SOLUTION OF NOISE PROTECTION

To achieve a successful model for noise management, assessment of the state of the noise level and taking the appropriate measures and methods for noise reduction, it is necessary to have as accurate as possible information about the characteristics of the noise itself. This information is determined by measuring the characteristic size of the noise in the frequency, amplitude and time domain.

3.1 Contribution of light lining to insulating power of solid wall

Light coating or thin barrier added to a solid wall to increase its insulating power is joined to it in some places very fixed. A flexible way of joining is adopted (Fig. 5 a). As a result of such attachment, acoustic bridges are formed and over them part of the sound energy is transferred from the solid wall to the light coating. Therefore, the insulating power of this structure is much lower than it would be an ideally accomplished double barrier. However, this added light barrier increases the insulating power of a solid wall in the frequency range between the resonance frequency f_0 of the complex wall and the coincidence frequency fc of the light lining. For this case, the frequency of the onset of action of a rigid connection, that is, the start of operation of the acoustic bridge f_B is characteristic too.



a) b)

Fig. 5. a) Solid wall with flexibley joined light lining b)Diagram of insulating power in a function of frequency

The frequency of resonance is defined according to the same formula as for a double barrier:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1,8\cdot\rho\cdot c^2}{b}\left(\frac{1}{m_{s1}}+\frac{1}{m_{s2}}\right)} = 80,23\sqrt{\frac{m_{s1}+m_{s2}}{b\cdot m_{s1}\cdot m_{s2}}}\ [Hz] \quad (3)$$

where m_{s1} and m_{s2} are surface masses of solid wall and light lining, respectively, and b distance between lining and wall. In these cases the surface mass of solid wall is significantly higher than the mass of the lining ($m_{s1} >> m_{s2}$) so practically a resonance frequency f_0 depends only on a surface mass of lining m_{s2} and its distance from the wall - b.

The frequency of onset of action of acoustic bridges for flexible connection is given by (4)

$$f_{BL} = f_0\sqrt{\frac{e\cdot f_c}{c}}\ [Hz] \quad (4)$$

In the formula (4): c – speed of sound, f_c – coincidence frequency of lining, e – distance between joining spots.

Increasing of insulating power within the frequency range from f_b to $f_{c/2}$ is in the case of flexible joining:

$$\Delta L_{BD} \approx 20\log\left(f_c\cdot e\right) - 45\left[dB\right] \quad (5)$$

The frequency of coincidence is calculated according to the formula:

$$f_c = \frac{c}{2\cdot\pi\cdot b} \approx \frac{55}{b}\ \left[dB\right] \quad (6)$$

The surface mass of conveyor wall and light lining is calculated according to the formula (7).

$$m_s = d \cdot m_t \left[kg/m^2 \right] \quad (7)$$

Where is: d – barrier thickness in cm; m_t – surface mass of materials $\left[kg/m^2, cm \right]$ (Table value).

Improvement of insulating power of the light lining is shown in the Fig, (5 b)) by the ABDE curve. On the frequency of coincidences insulating power is weakening, depending on the muffling value of light lining, and above this frequency is growing by the speed of 15 dB/okt.

3.1 Technical Solution of light lining of wood chip conveyor

In order to enable an efficient design of protection system against conveyor noise, it is started from the theoretical model of light acoustic lining. Understanding the possibilities of technical implementation, a final solution of chip conveyors noise protection is adopted in the factory of plywood.

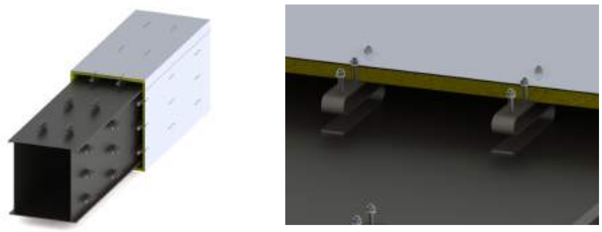


Fig. 6. Technical solution of conveyor light lining

First, the supporting structure of the lining consisting of flexible spacers in the form of the letter S are made then welded to the entire body of the conveyor. Before bending the spacers, the holes are drilled and bolts are welded for joining with lining. Lining consists of an insulating material (Azmafon A) and thin aluminum sheet protecting the absorbing material against weathering.

Conveyor body is made of steel plate 5 mm thick. The absorbing coating layer has a thickness of 20 mm, and the aluminum sheet is 0.7 mm thick. Distance between spacers is 500 mm. Surface mass of steel m_{s1} is 76,84 kg/m^2, and surface mass of aluminum 27,6 kg/m^2. Distance between the conveyor body and aluminum sheet is b = 70 mm.

Based on the adopted constructive dimensions and the formula 3÷7, the characteristic frequency of light lining put on the solid wall (body of the conveyor) can be calculated, as shown in Figure 5 b).

Values of the characteristic frequencies of light lining and the expected effect of reducing the level of noise are:

$f_o \approx 25\,Hz$, $f_c \approx 786\,Hz$, $f_{BL} \approx 27\,Hz$, $\Delta f_{BP} \approx 6.9\,dB$.

4. EFFECTS OF NOISE PROTECTION SOLUTION

For evaluation of performed technical solution, measurements of the noise level were made after making of conveyor light lining.

Measurements were performed at the same measuring points on which noise measurement had already been done before the sound protection.

Equivalent noise level around conveyor, on the average, is decreased by 8 dB (A). None of the measuring point is determined by the impulse character of noise.

Equivalent noise level at the measuring point in a residential area is reduced by 2.5 dB (A).

Table 4Noise levels in a settlement, after sound protection

Pos.	L_{Aeq} [dB(A)]	L_{AImax} [dB(A)]	L_{AFmax} [dB(A)]	ΔL_i [dB(A)]
MT_1	62.2	68.9	67.7	1.2

Another important result is the loss of the pulse at the measuring point in a residential area so that the referent noise level is reduced by another 5 dB (A). A total effect in protecting the conveyor is a reduction of noise level at the measuring point of 7.5 dB (A).

5. CONCLUSION

An expected effect of reducing the noise level in a residential area is achieved by the noise protection measures. Actual noise reduction enabled plywood factory work during the reference day time. Technical solution for the noise protection of the chain conveyor may be used to protect other conveyors in the factory, as well as in other similar cases.

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