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DESIGN AND ASSESSMENT OF THE EFFECTIVENESS OF ACOUSTIC MEASURES IN THE WORKING ENVIRONMENT

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Abstract: Reducing noise in the working environment is currently important, both in terms of meeting the obligation to comply with limit and action values, but also in terms of increasing the quality of the working environment. Workers in industrial production are often exposed to excessive noise. The reduction of noise in the working environment can in some cases be achieved in relatively simple ways, mainly by implementing measures that prevent the spread of noise along the transmission path. The first task in designing noise reduction modifications is to know the current state of the acoustic situation. Noise abatement measures will improve the working environment for employees and reduce the overall impact on human health. An important part is the proposal of measures to reduce noise with the subsequent implementation of these measures. During the design of the measures, it is necessary to take into account the suitability of the materials, the design solution and the financial complexity. After the implementation of the measures, noise measurements are performed and the effectiveness of the implemented measures is evaluated.

Keywords: noise, measurements, acoustic measures, design

INTRODUCTION

Noise reduction was implemented at a pair of specific workplaces, in a company for the production of automatic washing machines. At the workplaces, the output control of automatic washing machines is performed in the form of testing in individual modes. Within the solution of acoustic modifications of the given workplaces, the task was divided into the following stages [6,7]:

- Initial inspection of workplaces and performance of preliminary measurements to assess the acoustic situation,
- Proposal of measures to reduce noise in the workplace,
- Noise measurements performed before the implementation of the measures,
- Implementation of specific measures carried out by an external contractor,
- Noise measurements performed after the implementation of noise reduction measures,
- Evaluation and assessment of the effectiveness of the implemented acoustic modifications [8].

DESCRIPTION OF WORKING ENVIRONMENT

Output control workplaces (Figure 1) are located directly in the company's production facility, where the production of automatic washing machines is performed. Testing of washing machines is performed at workplaces of output control. One workplace is designed for testing top-loaded washing machines (TL - top loader), the other workplace for front-loading washing machines (front loader). Output control workplaces are structurally separated from the surrounding production. They are located in separate rooms formed by a steel structure with sandwich walls. The entrance to the workplace was solved by a pair of sliding doors. The entry of the washing machines is ensured by means of automatic conveyor belts through the inlet opening, from where they are manually taken for testing. The inlet opening cannot be closed. In close distance of the inlet there is a washing machine packaging workplace.

Both workplaces are almost identical in size, construction and construction. The dimensions of the workplace are 12.8 x 8.0 x 3.5 m. The walls and ceiling are made of sandwich panels filled with PUR foam, with plastic windows on the ceiling and around the perimeter [4,10]. The floor is smooth concrete with anti-slip treatment.

There are operators at the workplace who perform testing of washing machines and then process and evaluate the performed tests.

In close distance of both workplaces, there are workplaces for washing machines. At a distance of about 10 m from the workplaces of the output control, there are assembly lines and a paint shop. In the close distance of the workplaces, there are also communication routes in the immediate vicinity, along which forklifts and other mechanisms for the handling and transport of material and components pass regularly.

Figure 1. Output control workplace

ANALYSIS OF CRITICAL ELEMENTS

— Input openings

The most problematic place in terms of noise transmission at the exit control workplaces are the openings through which

the washing machines enter the workplace via conveyor belts. The inlet openings are permanently open without the possibility of closing them. In the close distance of the entrance of the washing machines to the workplace, there is an immediate packaging workplace, which significantly affects the noise in the interior of the exit control workplace, mainly through the passage of noise through the entrance opening. The entrance opening has dimensions of 1.8 x 1.8 m at the FL workplace and 4 x 1.8 m at the TL workplace. A view of the inlet opening is shown in Figure 2.

Figure 2. Input openings for washing machines

— **Entrance door**

The entrance door is used for employees to enter the exit control workplace. At the workplace there is a pair of entrance doors placed opposite each other. The door is currently designed as a retractable door, and even with the door closed, significant leaks can be detected. There is also an unnecessary hole in the handle area. These facts have a significant share in the transmission of noise from neighboring facilities and communication routes. A view of the entrance door is shown in Figure 3.

Figure 3. Entrance door

— **Reflective surfaces**

The inner surfaces of the walls and ceiling are hard and smooth, very well reflective, as they are formed by sandwich walls with a metal surface with a large number of glazed surfaces [3]. A view of the interior of the workplace is shown in Figure 4.

Figure 4. Interior of the workplace

DESIGN OF NOISE REDUCTION MEASURES

The design is processed based on the requirements for the acoustic quality of the laboratory interior for testing washing machines, which were specified by the customer. Following mutual consultations, the following requirements were set:

- reduction of noise in the laboratory on the minimum health and safety requirements for the protection of workers from the risks related to exposure to noise.
- creating a higher acoustic quality of the interior.

Operational tests of washing machines are carried out in the laboratory. Workers perform part of the hearing tests - the fault is manifested by a change in the acoustic parameters of the tested washing machine.

In accordance with the requirements, the following anti-noise measures have been proposed (applies to both workplaces) [9]:

- Implementation of sliding doors for the entry of washing machines into the workplace. Create these doors from acoustic material. The operation of the door must be automatic (the door responds to the presence of the washing machine on the conveyor) or manual (by pressing the control). Door drive system is up to decision of the supplier. The lower part of the door (up to the height of the conveyor) can be fixed. The door must allow the washing machines to be handled without any problems.
- Sealing (reconstruction) resp. replacement of the current sliding entrance door to the laboratory. This mainly involves removing the holes for the handle and covering the gap between the door and the laboratory structure.
- Increasing the acoustic quality of laboratory interiors by reducing the reverberation time, by installing sound-absorbing panels on the walls between the windows, or on the ceiling and structure. These panels absorb part of the noise penetrating through the cab structure, absorb the noise that spreads inside, reduce the reflection of noise from the interior walls of the laboratory. These panels must meet hygienic standards and their surface must be washable [1,2].

On the basis of the implemented proposals, the mentioned measures were also implemented at the given workplaces. In

the following figures. 5-7 shows the anti-noise adjustments made.

Figure 4. Roll doors

Figure 5. Acoustic entrance door

Figure 6. Installed sound absorption materials

NOISE MEASUREMENT RESULTS

Measurements were performed at both workplaces FL and TL. Measurements were performed at eight measuring points at each workplace, 4 measurements were indoors and four from the outside, while they were oriented perpendicular to each other at a distance of about 1 m from the dividing walls or in another if the microphone could not be placed for spatial reasons [5].

Noise measurements were performed during the standard operation of the surrounding workplaces, while all tested washing machines were shut down at the output control workplace, and there was no noise source at the workplace. Measurements were performed at identical locations before and after the implementation of acoustic measures.

In the following Table 1 presents the results of noise measurement before the implementation of acoustic modifications.

Table 1. Result of measurement before measures application

Measurement point	Before measures		
	Equivalent sound pressure level $L_{Aeq,T}$ dB		Attenuation dB
	Interior	Exterior	
M1	74.7	79.9	5.2
M2	68.6	76.8	8.0
M3	68.8	78.0	9.2
M4	69.2	77.1	7.9
M5	78.2	81.3	3.1
M6	72.7	78.7	6.0
M7	70.8	80.1	9.3
M8	70.9	78.3	7.4

In the following Table 2 presents the results of noise measurement after the implementation of acoustic modifications.

Table 2. Result of measurement after measures application

Measurement point	Before measures		
	Equivalent sound pressure level $L_{Aeq,T}$ dB		Attenuation dB
	Interior	Exterior	
M1	54.9	80.7	25.8
M2	51.3	76.5	25.2
M3	52.1	76.8	24.7
M4	51.0	75.1	24.1
M5	54.7	80.7	26.0
M6	51.9	77.4	25.5
M7	50.1	77.7	27.6
M8	52.5	76.6	24.1

CONCLUSIONS

From the results of noise measurements performed before and after reconstruction, we can state the following:

- External noise around workplaces was comparable during a series of both measurements,
- Noise in the interior of workplaces before making adjustments ranged from 68.8 to 78.2 dB, which results in noise attenuation in the range of 3.1 to 9.3 dB compared to the values measured outdoors,
- Noise in the interior of workplaces after adjustments ranged from 50.1 to 54.9 dB, which results in noise attenuation in the range of 24.1 to 27.6 dB compared to the values measured outdoors,
- When comparing the noise in the interior of the workplace before and after the modifications, it is obvious that the noise was reduced in the range of 18.2 to 23.5 dB at the individual measuring points.

From the measured data before and after the implementation of measures and their comparison, it is clear that in the interior of workplaces there was a significant reduction in noise through the implementation of the proposed anti-noise measures. Based on the measured values, it follows that even during an 8 - hour stay at the workplace, the action values of the normalized sound level will not be exceeded [10].

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