Advances in Science and Technology Research Journal
Volume 11, Issue 4, December 2017, pages 220-224
DOI: 10.12913/22998624/80310

Research Article

DESIGN AND EFFECTIVENESS VERIFICATION OF SOUND REDUCTION MEASURES IN PRODUCTION HALL

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Received: 2017.10.15
Accepted: 2017.11.01
Published: 2017.12.05

ABSTRACT
The main aim of the work described in this paper was to design and validate measures to reduce noise levels in a training center. This training center serves for the practical training of students with the focus in the shaping and machining engineering products. Reduction of noise in the training center was mainly due to the clarity and hearing of the spoken word between the lecturer and students, as well as to reduce the risk of hearing damage. In order to reduce noise levels, it was proposed to overlap the training center with a roof structure filled with sound absorbing material in two solutions. The noise absorption coefficient of the selected material was determined on the impedance tube. For verification of effectiveness, measurements of equivalent A sound levels were made before and after realization noise reduction measures. Reduction of equivalent A sound pressure levels after the noise reduction measures are between 15.5 dB and 17.5 dB depending on the measuring point and the operating mode. The effectiveness of the implemented measures reaches a good level, as noise was reduced to the recommended legislative level.

Keywords: sound insulating measures, sound analysis, sound measurements, design.

INTRODUCTION

At present, great emphasis is placed on reducing noise in manufacturing facilities in terms of health and hearing loss as well as for the clarity of the spoken word among workers. For this purpose, there are many ways to reduce the level of noise in workplaces, such as sound-absorbing walls and barriers between workplaces, soundproofing covers as well as various building treatments using sound absorbing materials. When designing noise reduction measures at workplaces, we draw on the theoretical and practical knowledge and recommended procedures for designing the low-noise workplaces described in books and documents Ver and Beranek in chapter 12 [1], Liptai R. G. [2], Zajac J. et al. [3, 4] and STN EN ISO 11690-2: 1999 [5].

Porous absorbent materials are currently applied in several areas where acoustic energy needs to be reduced in a noisy space and environment. Multilayer configurations (sandwich structures) that can be comprised of multiple porous materials, air spaces, and the like, are used to improve the sound-absorbing properties in a wide frequency range. The air gap behind the porous material improves mainly sound absorption in the low-frequency range. Physical knowledge of sound absorbing materials, as well as the mathematical and empirical relationships of the sound absorption principle, are known from several books and documents [6-11].

MATERIALS AND METHODS

The workplace is located in the manufacturing hall on an elevated floor of 4.3 m above the level of the base area of the production hall. The total floor area is 76.4 m^2. The training center serves to provide practical lessons for students of a secondary vocational school. The purpose of the facility is to enable students to develop the practical skills needed and usable in the working process.

The main source of noise is the production operations carried out in the production hall, in particular the aluminum surface finishing machine and pneumatic blowing equipment.

The workplace is separated from the surrounding space by vertical bars of sandwich construction (trapezoidal sheet with mineral wool filling) with a height of 2.3 m, this space being without a ceiling structure. Through the open upper space, acoustic energy penetrates the production hall into the training room.

Noise measurement was performed during standard production in the production hall in the following two operating modes:

- surface finishing machine active,
- surface finishing machine inactive.

Designing the measures at the training center located in the production hall, the first step was to diagnose the acoustic situation of the production hall and the specific area of the training center [14, 15]. Norsonic sound analyzers were used to measure the current state. The measurements were carried out in two measuring points at the training center. The measurements were made during two different operating modes of the noise sources in the production hall. Subsequently, the scope and technical options for noise reduction adjustments were analyzed. The space is located in the production hall on the elevated platform. The space of the training center is separated from the surrounding area by peripheral walls of the production hall and on one side by sandwich panels with PUR foam. A critical element of this space is the lack of roof overlays. After these analyses, a design and material design of the roof structure was carried out. The condition was to maintain access to this space through a crane, as it is necessary to manipulate the machine tools according to the material. An inspiration for these solutions we found in articles [12, 16].

The design was done in two variants. The material solution was made on the basis of realized measurements, the noise level and its character, and noise reduction to the required level. After the design was made, a variant was selected in the given space. Subsequently, verification measurements of the noise levels at the training center were carried out to assess the effectiveness of the proposed and implemented modifications.

DESIGN OF NOISE REDUCTION MEASURES

Acoustic requirements for noise barriers

Due to the character of the space and noise sources, a clear solution is to create a ceiling of the room from a suitable acoustic material, thereby preventing the transfer of acoustic energy into the training room.

Noise walls, resp. acoustic partitions and ceilings must provide sufficient sound insulation. Gaps (openings, leaks) can reduce the attenuation properties of noise barriers. For this reason it is also necessary to seal the joints between the base of the noise barrier and its elements. Due to the measured equivalent sound levels, we suggest using an acoustic material with the weighted sound reduction index RW = 30 dB.

Constructional and material design of acoustic ceilings

To reduce the level of noise we propose to build an acoustic ceiling. The basis of the acoustic ceiling is the sound-absorbing mate-

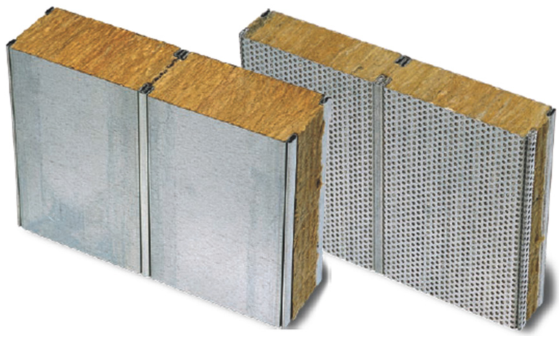

Fig. 1. Material solution for the acoustic panel

Table 1. Properties of proposed acoustic panel

Thickness of mineral wool filling [mm]	Weight [kg/m^2]	Dimensions [mm]	Weighted sound reduction index R_W [dB]	Overall heat transfer coefficient [W/m²K]	Thickness of outher sheet [mm]	Thickness of inner sheet [mm]
100	20,60	1150x2000	29-34	0,43	0,60	0,50

Table 2. Results of measurements – before measure realization

Measurement point	Equivalent sound pressure level, $L_{Aeq,T,}$ dB(A)	
	Surface finishing machine active	Surface finishing machine inactive
M1	80,7	73,3
M2	81,2	74,6

Table 3. Results of measurements – after measure realization

Measurement point	Equivalent sound pressure level, $L_{Aeq,T,}$ dB(A)	
	Surface finishing machine active	Surface finishing machine inactive
M1	63,2	57,8
M2	63,8	58,8

rial placed between metal sheets, the inner part being perforated to achieve higher acoustic absorption. As a sound insulation material, we design a mineral wool with a thickness of 80-100 mm. Currently, a number of modular panel systems are available on the market to meet the requirement of the RW = 30 dB weighted sound reduction index, which is considered to be sufficient to implement the design. This study does not deal with the detailed design of the proposed acoustic ceiling. It is also possible to choose different types of surface treatment (sheet, plastic, polyester, PUR layer, PP foam) [13]. The material solution of the acoustic panel is shown in Fig. 1. The following table shows typical features of the proposed acoustic panel.

The sound absorption parameter of the material that was designed for the sound absorption fill in the roof structure was determined using an impedance tube for the frequency range from 50 Hz to 2500 Hz. By comparing the α (-) sound absorption coefficient and the measured sound level LAeq (dB), we have confirmed the suitability of the 100 mm mineral wool to be used in the training center area before implementing the measures (see Fig. 2). The sound absorption coefficient is frequency dependent and, in general, the sound absorption of fibrous materials increases with the increasing frequency of sound. A sound absorption coefficient is a dimensionless number and the higher number means greater absorption of acoustic energy in the materials.

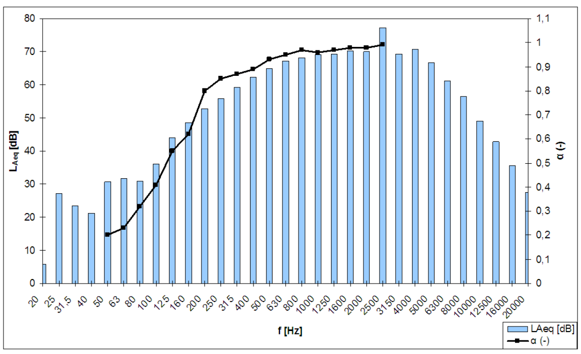

Fig. 2. Frequency spectrum of sound and sound absorption of material

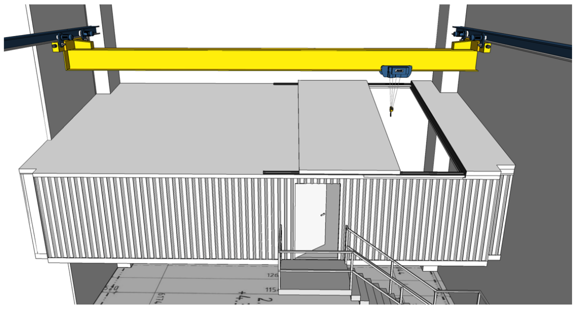

Fig. 3. Layout of acoustic ceiling - partly removable

During the design realizations, it was necessary to take into account the requirement of the client to maintain crane access to the training room (material handling, machines, tools, etc.). The construction of the proposed acoustic ceiling is designed in two variants that are different in access to the training room. The ceiling is designed for the possibility of anchoring the acoustic ceiling to beams in the wall in the production hall below the slope. On the other hand, the acoustic ceiling will be anchored to the beams in an existing space girder with a height of 2.3 m.

Variant no. 1 - partly removable acoustical ceiling. This variant is designed of the pushing mechanism one part of the acoustic ceiling will be horizontally retractable. The movement can be secured by the rail mechanism or, other appropriate system. The removable part of the ceiling

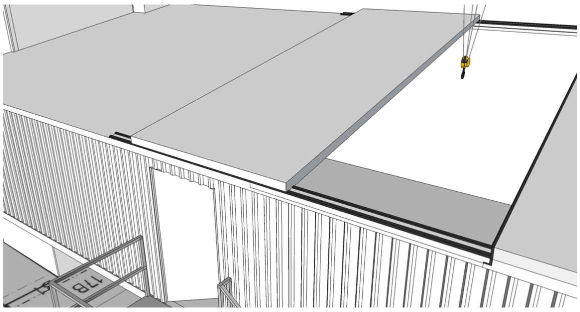

Fig. 4. Layout of acoustic ceiling - partly removable (detail)

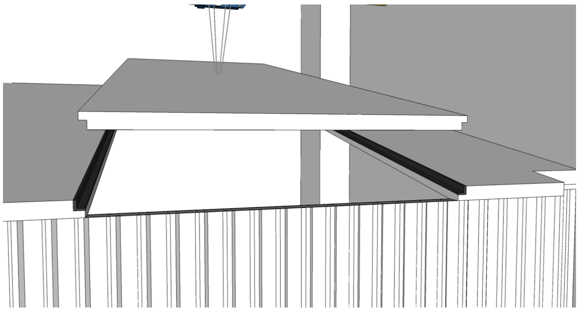

Fig. 6. Layout of acoustic ceiling - partly detachable (detail)

must be structurally connected to one unit. The arrangement of the acoustic ceiling is designed and illustrated in Fig. 3 and 4.

Variant no. 2 - partly detachable acoustical ceiling. This variant is designed that the part of the acoustic ceiling will be detachable. Manipulation with the detachable part would be secured by a bridge crane. The detachable part of the ceiling must be structurally connected to one unit. An arrangement of the acoustic ceiling is designed and illustrated in Fig. 5 and Fig. 6.

In both variants, the edge sections will be firm. An important part of the realization of the acoustic ceiling is the sealing of all the contact surfaces of the proposed acoustic ceiling around the perimeter (e.g. rubber) as well as the contact surfaces between the fixed and movable parts of the acoustic ceiling.

RESULTS

Noise measurement results from individual measuring points are shown in Table 2, Table 3 and graph in Fig. 7 during different operating modes before and after sound insulating measure realization. Measurements were carried out in two measurement points M1 and M2 in the training room.

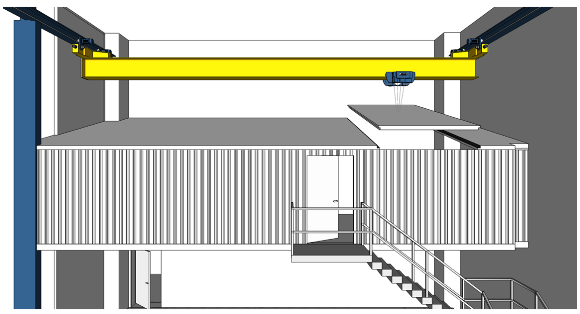

Fig. 5. Layout of acoustic ceiling - partly detachable

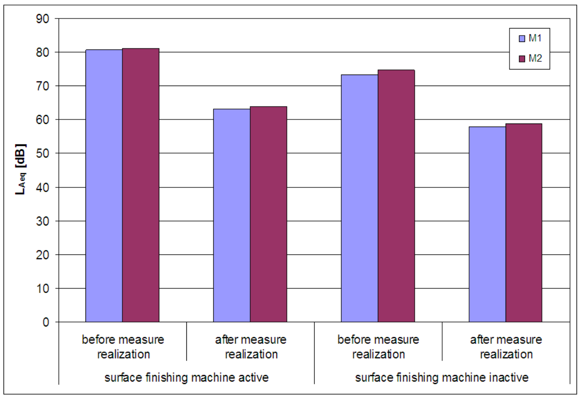

Fig. 7. Graphical comparison of measured results

From the measured data, it can be stated that the measures taken to reduce noise levels are effective, as there is no distraction from the outdoor environment in the training area by the spoken word of the lecturer worker during the lesson. Equivalent A sound pressure levels have been reduced from 15.5 dB to 17.5 dB depending on the measurement and operating mode. Reducing equivalent A sound pressure level in training centers was necessary not only for listening to the spoken word but also for the safety and health of students and teachers from excessive noise.

CONCLUSIONS

This paper presents noise measurements and design for noise reduction measures at production hall in training center and we can conclude:

- Measurements were carried out directly in the training center, as a basis for design noise reduction measures.
- Based on these measurements and location of noise sources, a proposal for measures to reduce noise in the training center was carried out.

- Designed measures - Acoustic ceiling build is designed in two variants (removable and detachable ceiling).
- By implementing these measures of selected variant, we expected a reduction in noise in this area due to external noise sources at the level about 60 dB. This value will depend on the quality of the processing of these proposals.
- When installing, it is necessary to ensure a consistent sealing of all contact surfaces, minimizing the noise transmission to the training center.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-15-0327 and by the Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic under the contract no. KEGA 048 TUKE-4/2015.

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