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POSSIBILITIES OF NOISE LOAD ELIMINATION IN PRODUCTION

Miroslav ŽITŇÁK*[1], Jana LENDELOVÁ[1], Zuzana PIVARČIOVÁ[1],
Maroš KORENKO[2], Paweł KIEŁBASA[3], Petr DOSTÁL[4]

[1]Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Nitra, Slovakia; jana.lendelova@uniag.sk (J.L.), zuzzkap@gmail.com (Z.P.)
[2]Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Design and Engineering Technologies, Nitra, Slovakia; maros.korenko@uniag.sk
[3]University of Agriculture in Krakow, Faculty of Production and Power Engineering, Division of Mechanisation and Energy Technologies in Agriculture, Krakow, Poland; pawel.kielbasa@urk.edu.pl
[4]Mendel University in Brno, Faculty of AgriSciences, Department of Technology and Automobile Transport, Brno, Czech Republic; petr.dostal@mendelu.cz
*correspondence: miroslav.zitnak@uniag.sk

In a pleasant and healthy work environment, employees are able to fully devote themselves to work, which is reflected in their work performance and a positive approach to work. This research paper focuses on changing the management approach of a selected company to physical factors of the work environment. The focus was targeted at looking for possibilities to change the work environment, which would create wellbeing for its employees, as well as to the exposure of a worker to noise in the work environment and the possibility of its elimination in a particular manufacturing plant. Based on measurements it was found out that the noise exposure values on the machinery had been exceeded. Based on the findings, two corrective technical measures were proposed to reduce noise in the workplace. The first technical measure was to cover the ultrasonic welders with acoustic covers; the second was to cover the fixture itself. However, the fixture covering was removed due to several negative effects on labour productivity and increased costs. After the implementation of technical measures, the measurements were taken once again and based on the results, the organizational measures were proposed.

Keywords: exposure of noise; action; method

Health and safety in the workplace are an important part of management systems of organizations and government bodies in most countries of the world. However, despite the increasing level of health and safety management, the direct consequences of risk factors in the workplace are considerable (Radosz and Pleban, 2018).

If an employer takes health and safety as a priority in caring for its employees, it is a huge help to society as a whole. The company cannot function properly if suitable working conditions are not created (Kangalov et al., 2022). If working conditions are neglected, there is an increase in accidents at work, damage to health, and occupational diseases (Lozrt et al., 2022). As a result, morbidity is rising, labour productivity is declining, incapacity for work is prolonged, and thus the economy and the quality of life of the society as a whole are affected (Pačaiová and Ižaríková, 2019).

In their work environment, employees are affected by several factors that can pose health risks. When evaluating the effects of the work environment on the health of employees, it should be kept in mind that one's health is an interaction of his/her lifestyle, work factors, environment, and, last but not least, the genetic factors. As the length of working life of an ordinary person is about 40–50 years with an optimal daily 8-hour working time, people spend about one third of their productive age at work (South, 2013).

The most neglected impact of noise on health is in the work environment. The most commonly reported occupational disease in the European Union is hearing loss due to excessive noise exposure. One in five employees must raise their voice while working due to an increased noise (Lumnitzer et al., 2014).

Pawlaczyk-Łuszczyńska et al. (2016) state that in years 1998–2002, hearing loss was in the first place in terms of the number of diagnosed cases of occupational diseases, while the percentage decreased from 28.7% in 1998 to 7.2% in 2014. Regarding the number of cases of hearing loss, they dropped from 3385 cases in 1998 to 169 cases in 2014. The respondents in the study were mostly men (74%) who were exposed to noise of approximately 90 dB for 11 years at average daily exposure. The study points out that all the respondents suffered from hearing loss corresponding to the World Health Organization classifications. The findings of Sriopas et al. (2017) confirmed that the noise of 86–90 dB (A) and more than 90 dB (A) significantly increased the risk of hearing loss in both ears. Noise levels significantly above 90 dB (A) increased the incidence of hearing loss in both ears. Workers working in these conditions for more than 10 years had significantly developed hearing loss in one ear.

Noise is identified as the most common occupational exposure in the workplace (Davies et al., 2005). Chronic occupational noise exposure may be associated with an

increased risk of cardiovascular diseases, such as coronary heart disease (Gan et al., 2011; Melamed et al., 1999; Passchier-Vermeer and Passchier, 2000; Virkkunen et al., 2005). The study results of Lusk et al. (2010) suggest that reducing noise exposure through technical inspections or the consistent use of hearing protection by workers can positively affect health results of workers. The study of Sriopas et al. (2017) agrees with this statement. Occupational noise exposure is significantly associated with the prevalence of cardiovascular disease. The research of Gopinath et al. (2011) has shown a link between exposure to loud noise between 1 and 5 years spent in the workplace and an increased risk of stroke. Working in a noisy environment for 1 to 5 years can cause a 60% higher risk of mortality from cardiovascular diseases over 10 years compared to if employees were never exposed to noise. These findings could help to inform about prevention strategies focusing on people at increased risk of dying from these diseases.

Material and methods

At the selected workplace, which is evaluated in this research paper, ultrasonic welders are the main source of noise. Any other machinery in the workplace is not a potential source of noise.

This particular operation is the first operation on the line where the operator must first place the necessary material near the ultrasonic welder. Subsequently, the operator mounts the tube to the rubber plug on the cable (Fig. 1), and then, inserts half of the part of the plastic component called the adapter into the fixture on the welder and slides the rubber plug into the adapter (Fig. 2). The operator folds the second part of the adapter and welds both parts of the plastic together by pressing the two-hand lowering. After welding, the operator cuts the ear and the sprains on the adapter in case they were created by welding. Subsequently, he checks the width of the groove after welding and moves the piece towards the next operation, i.e., to produce the other side of the product also on the ultrasonic welder.



Fig. 1 Inserting the tube into the rubber plug

After the first measurement, ultrasonic welding operations were merged; the work position of the ultrasonic welding operator was added to them. The testing operation is performed by the line tester operator, and other operations are provided by the line operator. These employees take turns in the given operations at one-day intervals. The line operator is responsible for the preparation and assembly of cable products. There are no significant sources of noise in this position, but workers are affected by the noise from ultrasonic welders and the noise from surrounding workplaces. The tester operator performs both, visual inspection and inspection by a testing device, while being exposed to the noise from ultrasonic welders and the noise from surrounding workplaces. The ultrasonic welding operator performs welding using an ultrasonic welder, which is a significant source of noise. All workers on the given line work in 8-hour shifts with one 30-minute break. Employees are a significant part of their work shift exposed to noise.

The evaluation and measurement of the noise to which employees were exposed in the workplace, based on measurements by the type of work or work position, was performed according to the standards STN EN ISO 9612 (2010); STN EN ISO 4869-2 (1998); Regulation No. 115/2006; and Professional Guideline of the Ministry of Health of the Slovak Republic 30/2010.

Noise measurements were taken in the workplace during standard work activities. The measurement was performed for those work positions in which there were changes in the working positions of workers. The different positions of the employee's head in the room were taken into account. The microphone of the sound level meter was 0.4 m from the worker's head, the axis of the microphone was parallel to the direction of his view and on the side with greater noise exposure.



Fig. 2 Adapter ready for welding

At the same time, the three noise levels were measured at workplaces (Table 1):

– equivalent level *A* of sound L_{Aeq}, *T*;
– equivalent level *C* of sound L_{Ceq}, *T*;
– peak level *C* of sound pressure L_{CPk}.

The measurement length (*T*) was chosen so that L_{Aeq}, *T* characterizes the noise exposure of the employee during the work shift. Noise measurements were performed using the equipment of Norsonic a.s., Norway: the integrating averaging sound level meter NOR-140; the measuring microphone NOR – 1225; and the NOR – 1251 calibrator was used for calibration.

Results and discussion

The assessed value is the value that is compared with the allowable value. It is the normalized noise exposure level $L_{AEX,\ 8h}$ (Table 2) increased by measurement uncertainty (U_{LA}), and the measured peak level *C* of acoustic sound L_{CPk} increased by measurement uncertainty (U_{LC}), which are compared with the upper and lower exposure action values.

According to Regulation No. 115/2006, as amended by Ordinance No. 555/2006, the legal limits are set as follows:

a) exposure limit values $L_{AEX,\ 8h,\ L}$ = 87.0 dB and $L_{CPk,\ L}$ = 140 dB;
b) upper action values of exposure $L_{AEX,\ 8h,\ L}$ = 85.0 dB and $L_{CPk,\ L}$ = 137 dB;
c) lower action values of exposure $L_{AEX,\ 8\ h,\ L}$ = 80.0 dB and $L_{CPk,\ L}$ = 135 dB.

In Table 3, the upper, lower, and limit values of exposure are compared with the calculated values from Table 2.

Draft measures

We have suggested to cover ultrasonic welding machines to eliminate or reduce noise exposure to the lowest

Table 1 Measured values

No.	Work position, work activity, noise source	$L_{Aeq,\ Tn}$ (dB)	$L_{Ceq,T}$ (dB)	L_{CPk} (dB)	*T* (min:s)
1a	ultrasonic welding operator 1 W: welding of components (adapters) using an ultrasonic welder note: welding of a component NS: noise generated during welding of the adapter, noise from the surroundings	95.9	94.1	127.8	5:00
		95.6	93.8	127.0	5:00
		95.7	93.9	128.0	5:00
1b	ultrasonic welding operator 2 W: welding of components (adapters) using an ultrasonic welder note: welding of a component NS: noise generated during welding of the adapter, noise from the surroundings	87.1	85.9	118.2	5:00
		87.3	86.0	11.8	5:00
		89.3	87.8	116.4	5:00
2	line operator W: other operations NS: noise in the hall, noise from ultrasonic welders, handling with components	76.3	78.9	102.7	5:01
		76.0	78.4	111.0	5:04
		76.3	78.6	105.0	5:00
3	operator – tester W: testing of cables on machinery NS: noise in the hall, noise from ultrasonic welders, handling with components	76.9	78.6	112.2	5:09
		77.1	78.8	111.9	5:00
		77.0	78.8	112.4	5:00

W – work activity; NS – noise source

Table 2 Calculated values from the equivalent sound level A by conversion to a nominal 8-hour working day

Work position	$L_{AEX,8h}$ (dB)	U_{LA} (dB)	$L_{CEX,8h}$ (dB)	L_{CPk} (dB)	U_{LC} (dB)	$L_{AEX,\ 8h} + U_{LA}$ (dB)	$L_{CPk} + U_L$ (dB)
Ultrasonic welding operator 1	95.1	1.4	93.3	128.0	4.4	96.5	132.4
Ultrasonic welding operator 2	87.9	1.4	86.6	116.8	4.4	89.3	121.2
Line operator	75.9	2.0	78.4	111.0	5.0	77.9	116.0
Operator – tester	76.7	2.0	78.5	112.4	5.0	78.7	117.4

Table 3 Assessment of compliance with allowable values

Work position	Exposure limit value $L_{AEX,\ 8h,\ L}$	Upper action value of exposure $L_{AEX,\ 8h,\ a}$	Lower action value of exposure $L_{AEX,\ 8h,\ a}$	Exposure limit value $L_{CPk,\ L}$	Upper action value of exposure L_{CPk}	Lower action value of exposure L_{CPk}
Ultrasonic welding operator 1	*not exceeded	exceeded	exceeded	not exceeded	not exceeded	not exceeded
Ultrasonic welding operator 2	*not exceeded	exceeded	exceeded	not exceeded	not exceeded	not exceeded
Line operator	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded
Operator – tester	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded	not exceeded

* Use of sufficient hearing protection in a minimum attenuation of 10 dB

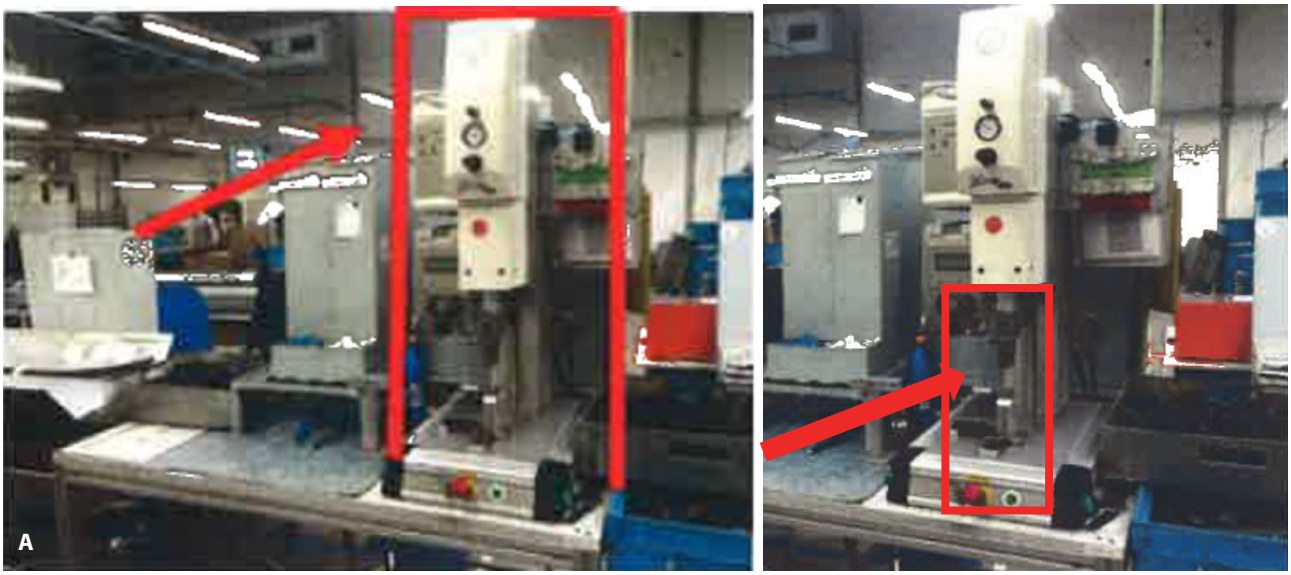


Fig. 3 A – primary adjustment design; B – secondary adjustment design

achievable level, taking into account technical progress and the availability of measures to eliminate or reduce noise, especially at the noise source by:

- Primary modifications at the noise source of individual devices (Fig. 3A): to provide individual noise sources with a suitable acoustic cover, while removing the tonal component by the value of inserted attenuation DIL ≥5–10 dB.
- Secondary modifications in the assembly space (Fig. 3B):
  a) by placing an acoustic screen between the primary noise source and exposed persons, the possibility of reduction by the value of inserted attenuation DIL ≥2–5 dB;
  b) by using suitable hearing protectors with a higher degree of noise attenuation.

Implementation of measures

The measures were performed by primary adjustments by covering both ultrasonic welders (Fig. 4). Covering was performed using metal profiles with PVC filling. From inside, a material made of polyurethane foam was used, which, thanks to its cellular structure, has good sound-insulating properties. The main area of its use is in the construction, engineering, automotive, and electronics industries. The type of polyurethane foam used is S220, which has a pyramidal surface and an absorption rate of α = 85%. A door with a transparent part was mounted on the front side to monitor the operation of the machine.

When doing the secondary adjustment of the fixture and after its testing, we decided to exclude this measure. The reason for doing so was that although the measure we took reduced the noise to a lower level, at the same time, we could observe several negative effects. One of them was the dissolution of the polyurethane foam material on the fixture, as there is a thermal bonding of plastics. Next, it caused problems when changing the operation of the machinery, which was done several times a shift. Thus, each setting was a waste of time in production. Also, the employees could not see where they were placing the components and, since each component has to be placed exactly into the fixture and subsequently on the cable, as a result, there was a risk of reducing the quality of products.



Fig. 4 Primary final adjustment of the ultrasonic welding machine cover

Repeated measurements after technical adjustments of the device

The measurement was repeated after making necessary adjustments. The measurement was taken after the primary adjustments, i.e., after covering the machinery. The results of the noise exposure measurements are shown in Tables 4 and 5.

After implementing the proposed measures, there was a change of production on the given line. It resulted in a reduction in the number of hours during which employees were exposed to noise sources. Noise exposure time was reduced to half of the week working time. At the same time, the work position of both ultrasonic welders was merged; one employee operated both welders. This means that the operator first welded one end of the cable and then the other end of the cable. Based on the time reduction and merging of operators, the exposure values from Table 5 were recalculated; the result of recalculation is shown in Table 6. The comparison with the legislation (US Department of Health and Human Services, 1998; Directive 2003/10/EC, 2020; The Control of Noise at Work Regulations, 2005) is in Table 7.

As part of the risk management plan, the measures resulting from the STN ISO 45001:2019 standard, EU directives, and studies by various authors have been proposed:

- employees are regularly briefed on work procedures and instructions to ensure noise reduction (Sinay, 1997);
- the employer promises to ensure regular maintenance of technological equipment, which means regular predictive maintenance, lubrication of the rotating parts of equipment, servicing of damaged parts of machinery, and replacement of damaged parts of the machine (Pačaiová and Ižaríková, 2019; Pačaiová et al., 2021);
- the employer will take technical measures to reduce the noise on the line – ultrasonic welding machine, due to the objectification of detected limit values (Fig. 4);
- all employees are immediately after their employment and then regularly (at least once every 2 years) trained in health and safety regulations; they are aware of possible risks due to noise exposure and the correct use of earplugs. A study by Verbeek (2012) confirmed that, when using earplugs, attenuation depends almost entirely on their correct insertion;
- the employer offers employees periodic preventive health examinations; an audiometric examination is also included;
- certified earplugs (type EAR Classic SNR = 28 dB, M = 24 dB) in sufficient quantity are provided for employees exposed to noise, to ensure their regular replacement for hygienic and health reasons (Table 7); research done by Sriopas et al. (2017).

Table 4 Measurement results

No.	Work position, work activity, noise source	$L_{Aeq,T}$ (dB)	$L_{Ceq,T}$ (dB)	L_{CPk} (dB)	T (min:s)
1a	ultrasonic welding operator 1 W: welding of components (adapters) using an ultrasonic welder note: welding machine in acoustic cover NS: noise generated during welding of the adapter, noise from the surroundings	91.9	90.1	115.9	5:00
		91.8	90.0	117.0	5:00
		90.5	88.7	115.9	5:00
1b	ultrasonic welding operator 2 W: welding of components (adapters) using an ultrasonic welder note: welding of a component NS: noise generated during welding of the adapter, noise from the surroundings, noise from welding machine no. 1	87.0	85.5	117.2	5:00
		86.2	84.7	119.6	5:00
		88.5	86.9	115.9	5:00

Table 5 Calculated values from the equivalent sound level A by conversion to a nominal 8-hour working day

Work position	$L_{AEX,8h}$ (dB)	U_{LA} (dB)	$L_{CEX,8h}$ (dB)	L_{CPk} (dB)	U_{LC} (dB)	$L_{AEX,8h} + U_{LA}$ (dB)	$L_{CPk} + U_{LC}$ (dB)
Ultrasonic welding operator 1	91.1	1.7	89.3	119.6	4.7	92.8	124.3
Ultrasonic welding operator 2	86.9	1.7	85.4	118.5	4.7	88.6	123.2

Table 6 Calculated values from the equivalent sound level A by conversion to a nominal 8-hour working day

Work position	$L_{AEX,8h}$ (dB)	U_{LA} (dB)	$L_{CEX,8h}$ (dB)	L_{CPk} (dB)	$U_{LC)}$ (dB)	$L_{AEX,8h} + U_{LA}$ (dB)	$L_{CPk} + U_{LC}$ (dB)
Ultrasonic welding operator	85.9	1.7	84.6	119.6	4.7	87.6	124.3

Table 7 Assessment of compliance with allowable values

Work position	Exposure limit value $L_{AEX,8h,L}$	Upper action value of exposure $L_{AEX,8h,a}$	Lower action value of exposure $L_{AEX,8h,a}$	Exposure limit value $L_{CPk,L}$	Upper action value of exposure L_{CPk}	Lower action value of exposure L_{CPk}
Ultrasonic welding operator	* not exceeded	exceeded	exceeded	not exceeded	not exceeded	not exceeded

* Use of sufficient hearing protection in a minimum attenuation of 10 dB

Table 8 Financial evaluation of draft measures

Measure	Unit amount (€)	Quantity (pcs)	Total amount (€)
Primary adjustments	600	2	1200
Secondary adjustments	150	1	150
Total	1350		

Table 9 Savings calculated over a period of 1 year

Type of savings	Unit price (€)	Quantity (pcs)	Total amount (€)
Risk surcharge, change of category from 4 to 3	0.07 per hour	4 employees × 160 hours	537.60
Noise measurement once a year in 4 risk categories	1100	1	1100
Total			1637.60

It should be noted that not every measure concerning occupational safety is just a cost. In this research, the cost of the measures spent during the measure proposals and their testing to reduce the noise exposure level is shown in Tables 8 and 9. In addition to the cost of the measures, there is of course a health benefit which cannot be quantified so easily.

The result of this work is the reduction of noise in the workplace through technical and organizational measures as well as the consistent use of hearing protection; based on this, it is assumed, as in the study of Lusk et al. (2010), that it will have a positive effect on the health of employees.

However, this work, as well as the work of Žiaran (2001) and Očkajová (2013) point out to the fact that reducing risks that negatively affect health, and taking measures can, in some respects, save employers' costs (Table 9). As the priority of every employer should be to ensure health and safety in the workplace (Act No. 124/2006; Act No. 355/2007), it can be concluded that seemingly simple measures can improve working conditions. Improving working conditions is a huge benefit for every employee. Employees, who see that their employer is ready to reduce risks (STN ISO 45001, 2019), take this as an additional work benefit and are willing to continue working for their employers. These employees do not change jobs, which (Hatina et al., 2007) is another saving for the employer.

Conclusion

The aim of this work was to evaluate the degree of health damage of employees from noise exposure on a selected technological line. A line that produces radiation systems for automobiles has been selected. The company places great emphasis on health safety at work and consistently monitors the parameters of the working environment.

Based on the fact that a very high level of noise risk was assumed on this line, it was necessary to determine the objective value of noise load. Noise exposure exceeded the upper risk action values, and the ultrasound welding workplace would have to be classified in risk category 4. Such a classification brings several negatives, which are associated with expenses and a high degree of damage to the health of employees.

Based on the evaluation of work activities on each work equipment, the measurement method for individual types of work, i.e., work positions, was used. Therefore, the operations were divided into three work positions. The first measurement confirmed that the two pieces of ultrasonic welders were the largest source of noise on the selected line. Other machinery was affected by the noise from the surrounding production and the ultrasonic welders, located nearby.

The two corrective measures were proposed. The first technical measure was to cover the ultrasonic welders with acoustic covers. The second technical measure was to cover the fixture itself. However, the fixture covering was removed due to several negative effects on labour productivity and increased costs.

After re-measurements using the first technical measure, the risk was reduced by 8.7 dB, which did not mean a complete avoidance of risk, but the level of risk was significantly reduced, and employees were assigned to risk group 3. Although risk category 2 was not met, it is possible to say that the working environment for the employees on the line was improved. The investment in shelter covers has returned to the employer. In the future, this measure will save the costs of risk. In order to bring the noise exposure below the limit value according to Regulation No. 115/2006, it was decided to keep employees with personal protective equipment to protect their health, specifically hearing protection with an attenuation of at least 10 dB.

The evaluated company is ready to reduce the risk of health damage of its employees, especially through collective and technical measures. Since ultrasonic welding is used in several workplaces, this solution is simple and practical to implement on other lines, where ultrasonic welding is used.

In the occupational health and safety management system, the assessment of health risks due to increased noise, its categorization, the assessment of working conditions, and the determination of the scope of health surveillance are of great importance. It is very important to brief employees about the risk of noise exposure and its effect on their health. The role of employers is therefore to reduce this risk to the lowest possible, achievable level.

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