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A NEW METHOD FOR DETERMINING THE EFFECTS OF EXPOSURE TO NOISE IN INDUSTRIAL WORKING ENVIRONMENTS

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ABSTRACT
The paper presents the results of theoretical and practical research dealing with the determination of the effects of noise on workers in an industrial environment. The ergonomic coefficient K_{er}, modified by the novel method presented in this paper, has been used as a measure for the effect of noise on workers. The new method has been tested on various workplaces in metal working industry. A comparison of the results obtained by the currently used standard method and the new method confirms the correctness of the basic idea of the new method, i.e. the need for a more complex approach to the evaluation of the effects of exposure to noise.
Keywords: ergonomic coefficient, noise, nature of noise, weighting factors, impulsive noise correction, tonality correction, new method

1. INTRODUCTION

While working, the worker is exposed to various strains and stressors, which all contribute to his stress. Noise in the working environment is one of the major and certainly most frequent stressors at work.
The ergonomic coefficient K_{er} can be used as an additional protection against the effects of noise on workers because it offers extra time for the human organism to recover [1].
During our study of the methodology for assessing the strains at work (to determine K_{er}) it occurred to us that the influence of noise on the value of K_{er} is perhaps evaluated too loosely. The reasons are the following:

1) Noise as a disturbing factor produces different effects on workers performing different tasks.
2) The correlation between the nature of noise (changes in noise level, interrupted noise, sudden short-term noise, etc.) and human efficiency at work is confirmed in literature [2-7].
3) The correlation between the characteristics of noise
   - frequency spectrum or frequency distribution of noise (high frequencies),
   - impulsiveness,
   - tonality,
4) EU directives regulating noise in a working environment [8, 9], from which the recent Slovenian legislation is derived [10], bring more severe criteria:
   - the daily limit value of exposure to noise is 85 dB,
   - the impulsive nature of noise has to be taken into account.

The objective of our work is to include the above mentioned facts in a new method which will serve to determine the effects of exposure to noise in a working environment.

2. NEW METHOD FOR DETERMINING STRAINS CAUSED BY EXPOSURE TO NOISE

The objective of the new method, presented in this paper, is to eliminate the deficiencies of the standard method by taking into account the complexity of the effects of noise on workers in a working environment. This means that the effects of exposure to noise will be assessed in terms of risk to health damage, physiological responses of the organism, efficiency at work and in the light of current standards. The new method consists of two parts:

- The new strain assessment procedure that incorporates the effects of the nature of noise, the characteristics of noise, the current standards on the protection from noise, and the influence of noise on different jobs;
- The new noise assessment approach that uses new noise measurement techniques (tonality and impulsive noise corrections).

2.1. A New Approach to the Assessment of the Effects of Exposure to Noise

The new approach to the assessment of the effects of exposure to noise consists of three steps (three Tables). The objective is to assess the influence of the level of noise and the degree of work (job) complexity, together with the nature of noise.

The steps are as follows:

1. In table 1 the work (job) to be performed is classified according to the mental effort it requires - determination of the type of work.
2. In table 2 we can find the basic points for the strain T_o with respect to the type of work (job) and the equivalent noise level.
3. In table 3 the extra points for the weighting factors T_{uf} are obtained with respect to the type (nature) of noise.

The sum of the basic points for the strain T_o and the points for the weighting factors T_{uf} represents the final number of points for the strain T.

In noise assessment, work is classified into six groups, from the mentally most demanding work A1 to the mentally least demanding work B3. The reason for this is in the fact that noise produces different disturbing effects on different types of work (Table 1).

Table 1. Classification of work

Type	Description of work
A1	The most demanding mental work (elaboration of concepts)
A2	Predominantly mental work (demanding office work), speech and telephone communication
A3	Routine work requiring concentration, simple office work, high precision assembly work, complex system control
B1	Supervision of a group of workers performing predominantly physical work, frequent oral instructions to workers, demanding assembly work, simple inspection tasks
B2	Less demanding work requiring concentration and caution, auditory attention and control of the environment, handling of devices, simple systems control
B3	Work demanding no mental effort or auditory attention

The new table (Table 2) is divided into two parts. The first part contains the effects of exposure to noise during mentally demanding work. The scale used for evaluation extends from 0 to 3 or 4 points respectively. The second part contains the effects of exposure to noise during mentally less demanding work. The evaluation scale extends from 0 to 2.5 points.

Table 3 shows our attempt to assess the additional effects of the type (nature) of noise on the worker irrespective of the measured noise values.

We studied the effects of the following different types of noise:

- continuous noise with disturbances
- fluctuating noise
- short-term noise
- noise spectrum (frequency distribution of noise)
- night-shift noise

on workers in terms of damage to the auditory system (impairment of hearing), physiological responses of the organism and work efficiency (work output).

Table 2. The basic evaluation points for T_o

T_o Points	Type of work		
	A1	A2	A3
0	<45	<50	<60
1	45-50	50-55	60-65
2	50-55	55-60	65-70
3	55-60	>60	>70
	B1	**B2**	**B3**
0	< 50	< 55	< 60
0.3	50-55	55-60	60-65
0.6	55-60	60-65	65-70
0.9	60-65	65-70	70-75
1.2	65-70	70-75	75-80
1.5	70-75	75-80	80-85
2.0	75-80	80-85	85-90
2.5	>80	>85	>90

Table 3. Points for weighting factors T_{uf}

Factor	Type of noise	Description	Type of work	T_{uf} points
1	Continuous noise with disturbances	The difference between L_{Aeq} (the daily noise level) and $L_{Aeq,Ti}$ (the level of disturbance during the time interval *Ti*) is greater than 10 dB(A) - under the condition that the disturbance lasts longer than 5 minutes and that L_{Aeq} > 80 dB	B1, B2, B3	+0.1
2	Continuous noise with disturbances	Elevated/lowered noise levels through a longer period of time - under the condition that the change > 5 dB	A1, A2 A3 B1, B2 B3	+0.3 +0.2 +0.1 +0.05
3	Interrupted noise	Noise interrupted by periods of effective silence, i.e. noise level below 70 to 75 dB, which depends on the frequency	B1, B2, B3	-0.05
4	Fluctuating noise	Noise variations in time, but never dropping below the level of effective silence	B1, B2, B3	-0.03
5	Short-term, sudden noise	Unexpected, instantaneous noise	A1, A2 A3 B1, B2 B3	+0.3 +0.2 +0.1 +0.05
6	Very high frequency noise	Very high noise levels above the frequency of 1 kHz; the corresponding time period is considered (the noise spectrum is assessed by the third octave frequency band analysis)	B1, B2, B3	+0.4
7	High frequency noise	High noise levels above the frequency of 1kHz; the corresponding time period is considered	A3 B1, B2, B3	+0.2 +0.2
8	Noise during night shifts	Night shift	A3 B1, B2, B3	-0.1 -0.1

2.2. New Approach to Noise Assessment

The objective of the presented new approach to noise evaluation in a working environment is to incorporate the harmful effects of noise impulses and tonality on workers into the method.

As all noise levels are measured throughout the workday, the worker's daily exposure to noise is denoted by L_{Aeq} instead of $L_{EX,8h}$, which is used in cases when not all noise levels are measured (periods of relative silence).

The equation is calculated in accordance with the standard ISO 9612 [8]:

$$L_{AITeq} = 10\log\left(\frac{1}{T_e}\sum_{i=1}^{n} T_i 10^{0.1\left(L_{Aeq,T_i} + K_{Ii} + K_{Ti}\right)}\right) \quad (1)$$

where L_{AITeq} is the equivalent noise level during the workday (T_e) with impulse and tonality corrections, K_{Ii} is the impulse correction during the time interval T_i, and K_{Ti} is the tonality correction during the time interval T_i.

3. APPLICATION OF THE NEW METHOD TO PRACTICE

The new method has been tested on 40 different workplaces in metal working industry. Obtained measurement results are used to determine the ergonomic coefficient K_{er} according to the presented new method, and to allow comparison, also according to the previous standard method (Table 4).

Table 4. The calculation of the ergonomic coefficient K_{er} (only 5 workplaces)

	New method							Standard old method		
Workplace	Work code	Weighting factors	Points T_{uf}	L_{AITeq} (dB)	Points T_o	Sum of points T_{uf} + T_o	K_{er}	L_{Aeq} (dB)	Points T	K_{er}
Torch cutting	B3	2, 4, 6	0.29	93.6	2.5	2.79	0.045	92.3	2.0	0.033
: :										
CNC machine tool	B3	4	-0.03	75.4	1.2	1.17	0.019	75.4	1.2	0.020
Foreman	B1	2, 3, 5	0.15	71.2	1.5	1.65	0.027	71.2	1.2	0.020
Plumber's work	B3	2, 4, 5, 6	0.1	100.4	2.5	2.6	0.042	95.9	2.0	0.033
Boiler house	B2	1, 2, 3	0.15	86.3	2.5	2.65	0.043	83.4	1.2	0.020

4. CONCLUSIONS

The new method for determining the effects of exposure to noise is so designed that it takes into account the whole complexity of the effects of noise on the worker in terms of damage to health, physiological responses of the human organism and efficiency at work. A more precise way of evaluating noise on the basis of impulse and tonality corrections is included in the new method. It is only logical that the obtained values of the ergonomic coefficient K_{er} are higher than the ones obtained by the standard method. The testing of the method on 40 workplaces in metal working industry has confirmed the correctness of our hypothesis.

5. REFERENCES

[1] Polajnar A., Verhovnik V.: Oblikovanje dela in delovnih mest za delo v praksi, Fakulteta za strojništvo, Maribor, 1999.
[2] Harris C. M.: Handbook of Noise Control, McGraw–Hill Book Company, New York, 1979.
[3] Loeb M.: Noise and Human Efficiency, John Wiley & Sons, 1986.
[4] Simonović M., Kalić D.: Buka - štetna dejstva, merenje i zaštita, Niš, 1982.
[5] Sanders M. S., McCormic E. J.: Human Factors in engineering and design, McGraw – Hill International Edition, New York, 1990.
[6] Croome D. J.,: Noise, buildings and people, Pergamon press, 1977.
[7] Gspan P.: Ekologija dela, Iskra in ZVD, Ljubljana, 1984.
[8] ISO 9612: Acoustic – Guidelines for the measurement and assessment of exposure to noise in a working environment, 1997.
[9] Direktiva Sveta o varovanju delavcev pred tveganji v zvezi s hrupom pri delu, 86/188/EEC.
[10] Pravilnik o varovanju delavcev pred tveganji zaradi izpostavljenosti hrupu pri delu, Ur. l. RS št.7/2001.
[11] Fras V.: Hrup v delovnem okolju in njegov vpliv na obremenitev človeka, Magistrska naloga, Maribor 2001.