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Social-economic and Ecological Criteria of Noise Control

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Abstract: When designing new and/or modifying pre-existing equipment, the problem of economic feasibility is always of prime importance . However, the economic feasibility is often a matter of discussion in various social aspect. To operate no aesthetic, noisy, dusty, gazed heavy machine with large number of visually fixed moving parts and gearing, it is often dangerous and even risky. The work productivity of such machines will always be reduced directly or indirectly because of psychological incompatibility of the workers and the machines or due to social damage related to often illnesses of workers or fluctuation of labors. The level of psychological and working compatibility of the operators of the machines in view of all modern requirements of ergonomics and design, are of second order effect.

Key words: Sociology, Economic Criteria, Ecology, Noise Control, Acoustic

INTRODUCTION

Let us consider how the material damage or material effect is connected with the noisy level of old or modern machines [1-5].

The standards and norms of ISO are stipulated to upgrade nosiness of machines by a limit spectrum, noise level (dB), integral noise level (dBA) or equivalent noise level (L_e). A scale of permissible work accommodation in conditions of the increased noise τ_g, also is precisely developed by the physicians, hygienists and by specialists in acoustics. Thus, it is possible to find the direct relationship between time and cost of work accommodation parameters in such conditions for example, in Germany the workers are paid in addition to their salary during stay in such condition. Thus, an opportunity arises to connect the work accommodation with the economical parameters [6-9].

Development of Social Economic Criteria: In order to improve the acoustic working conditions, the equivalent level reduced from L_{e1} to L_{e2} (acoustic effect $\Delta L_e = L_{e1} - L_{e2}$),
where, L_e is the equivalent noise level and L_{e1}, L_{e2} is the equivalent noise level before and after noiseless. Then losses and production costs are established by the value:

$$\Delta M = M_1(L_{e_1}) - M_2(L_{e_2}) \quad (1)$$

where, M is the material damage or head loss as a result of poor effect or due to normalization of noise circumstances, and $M_{1,2}$ is the material damage before and after holding measures. It is similarly possible to present the result of the reduction of work accommodation time in increasing noise conditions:

$$\Delta M = M_1(\tau_{g_1}) - M_2(\tau_{g_2}) \quad (2)$$

where, τ_g is the permissible residence time in requirements of noise. Thus, we have a scale of transition from ΔL_e to τ_g and logic conclusion on the opportunity finding the equivalent of economic (or social) and acoustic (or time) parameters describing a degree of imperfection of machines on due to noise factor. The losses and production costs conditionally are considered equal to zero at an equivalent level L (to time τ) not exceeding a norm:

$$M(L_e) = 0 \text{ at } L_e \le L_{enorm}, M(\tau_g) = 0 \text{ at } \tau_{g_1} \le \tau_{g_2} \quad (3)$$

where, L_{enorm} is the equivalent normative noise level. The recalculation of the excess of the machine noise level at the worksite, through parameter of permissible operating time, is made under the formula of reduction of an equivalent level (level of a sound) to permitted one:

$$\tau_g = 10^{-0.05(L_e - L_{enorm})} \quad (4)$$

Designing new non-noisy machine tool or modernization the technical effect ΔL_e can be achieved. The densities of permissible operating time is increased by size $\Delta\tau_g$, where temporary parameter of socio-economic effect noise control:

$$\Delta\tau_g = 10^{-0.05(L_e - L_{enorm})}.\left[10^{0.05\Delta L_e norm} - 1\right] \quad (5)$$

In formula (5), and in view of condition (3):

The given criteria meets the law of Weber-Fehner [10], studies of Selier [11]. It is possible to name the found criteria as social-ergonomic under the factor of noisiness. Using the traditional economic dependencies, it is possible to find annual economic benefit of modernization or of designing low noise equipment, i.e., an improved equipment with acoustic parameters:

$$B_y = (G - E_H.K)A_2 \quad (6)$$

where, G is the profit gain due to realization of production of the better quality numerically equal to reduction of losses and production costs ΔM, K is the specific capital investment connected with the improvement of quality of production, E_H is the normative factor of payback, and A_2 is the annual production of the better quality in the considered year.

According to the profit gain definitions, the reduction of losses and costs is attained only at the expense of economy of fund of the workers salary as a result of permissible operating time increase. the increase in noise and profit account related to production increase is not taken into account. According to it, the corrected gain of the profit $G^1$is defined under the formula:

$$G^1 = S \cdot T \cdot t \cdot \Delta\tau_g \cdot N \quad (7)$$

where, S is the production operator average salary per hour whose acoustic working conditions were improved, T is the number of working days in the year, t is the duration of a working hours per day, $\Delta\tau_g$ is the time parameter of the efficiency of noise control, and N is the number of production operators.

Thus, it is possible to define the socially-ergonomic-economic benefit precisely in order to reduce noise of the machines compared with the analogues or to modify of the equipment. As it is shown, the effect of noise control cannot be considered separately for other adverse ecological parameters lowering competitiveness and serviceability of the machine in view of the human factor, i.e., all set of ergonomic parameters, including design of the machine. For getting of the operative data on all basic ergonomic parameters the technique of demoscopic studies was used. The subjective opinions of the workers on parameters of machines were defined in view of their length industrial service, experience, age and sex. The methodical approach of unexpected interrogation with explanations and direct inspection was chosen: ergonomic parameters of the machine, such as, who far it is convenient to you to operate the given machine? and what adverse factors hinder you to do it with satisfaction?.

Various industrial sectors were inspected for 5 years. The questionnaires were distributed among the workers to reply the question: How far the followings are hindering you job performance at your worksite: dust content, inconvenience of operation, noise, bad lighting, temperature, and appearance of the machine?. The worker gives his estimated answer in the questionnaire as follows: 1: does not hinder, 2: slight hinders, 3: mild, 4: very much, and 5: extremely hinders. At processing results of interrogations the designations were used: k is the subjective estimation by the interrogated of a level of the adverse factor, k =1-5 is the number of the adverse factor, a=1-6, i is the sex of interrogated, i = I - man, i = II – woman, N_i is the total number of the interrogated men (women) and $n_\alpha^i(K)$ is the number of the interrogated men (women) who have estimated the factor by number K (totally on all objects was interrogated about 500 persons). As the basic quantitative characteristic of influence of the adverse factor we shall accept a value of an index of a hindrance [7]:

$$X^i_\alpha = \frac{1}{N_i}\sum_{k=1}^{5} Kn^i_\alpha \quad (8)$$

The results of demoscopic inspection can be presented as (1) table: (to each factor "a" for i = I; and II; (2) diagram: on vertical axis are the intervals K = 1,2... 5, and on each interval is the rectangular of the area proportional to the frequency of the value of a sign $\frac{n^i_\alpha(K)}{N_i}$ and on horizontal axis, $n_\alpha^i(K)$ or (3) polygons: on horizontal axis is the value of K and vertical axes is the frequency, Table 1 illustrate the calculations of hindrance index resulted from sociological inspection.

Table 1: Results of Sociological Inspection

Ecological factor	An index	
	i = I	i = II
Dust content	1.7	2.0
Inconvenience of operation	1.5	1.6
Noise	2.5	2.6
Lighting	0.4	0.5
Temperature	1.7	2.0
Appearance of the machine	1.4	1.7

Table 2: Criterion of Distinction

a	1	2	3	4	5	6
$\lvert t_\alpha \rvert$	2.8	1.7	0.8	15.7	2.8	7.5

In this case two point attract the attention: (1) the large index of a hindrance due to the industrial noise in compare with other adverse factors, and (2) more critical approach of the women over all factors, than men. The machined design factor takes the third place after dust content and temperature mode, being of close importance with to the factor of operation, which is typical and proves the correlation of the two factors. The question whether to consider a divergence on a sex casual is solved with the help of Student criterion with the calculated dispersion:

$$(S^i_\alpha)^2 = \frac{1}{N_i - 1}\sum_{K=1}^{5} n^i_\alpha(K)(K - X^i_\alpha) \quad (9)$$

$$S_\alpha = \sqrt{(S^I{}_\alpha)^2(N_I - 1) + S^{II}{}_\alpha(N_{II} - 1)} \quad (10)$$

The criterion of distinction is defined [7, 8 and 10]

$$|t_\alpha| = \frac{X^I_\alpha - X^{II}_\alpha}{S_\alpha\sqrt{\frac{1}{N_I} + \frac{1}{N_{II}}}} \quad (11)$$

which will have distribution Student with number of degrees of freedom: $(N_I+N_{II}-2)=K$. In Table 2, the critical meanings (importance) for distribution Student t(P,K), where, P is the given reliability, and K is the number of degrees of freedom are given. If $|t_\alpha| > t(t,k)$, it is necessary to consider distinction. Let P = 0.90, then t (0.90, 80) = 1.664.

Comparing criterion of distinction value $|t_\alpha|$ (Table 2) with the calculated criteria of comparison t(P,K), it is possible to make a conclusion, that with reliability it is necessary to consider (count) 0.90 distinctions of an index of a handicap for all adverse ecological factors, except for noise known. By a general parameter-ergonomic criterion of an estimation of conformity of the machine tool to the requirements of the operator or level of engineering. such estimation could be given by the experts, is the integrated index of ecological handicaps

$$X_{HH} = \sum_{\alpha=1}^{6} X^i_\alpha \quad (12)$$

As a result of perfection of the machine tool by the designers and manufacturers the index of handicap should decrease.

Let's proceed now to an estimation of material damage from set of adverse ergonomic parameters. The material damage by analogy with (1) can be expressed as:

$$M_i = X_{HH} \cdot t_H \cdot T \cdot Si \quad (13)$$

Where, $X_{HH} = \sum^{6} X^i_\alpha$ is the index of a handicap, %, t_H is the working hours, T is the number of working days in one year, and S_i is the hourly average actual salary, (the results of calculations on the machine are given in Table 3.

Table 3: Material Damage Calculations

i	X^i_{HH}	M
I	0.89	1394.5
II	0.9	1499.5

Material damage from ecology-ergonomic imperfection machine for the period of investigation shall be defined

$$M_i = X^i_{HH} \cdot X^i_\alpha \cdot t_n \cdot T\cdot, Si \quad (14)$$

Table 4: Damage Caused by Particular Factors

Ecological factor	M(I)	M(II)
Dust content	459.8	599.8
Inconvenience of service	404.85	497.8
Noise	674.75	779.7
Light exposure	107.9	149.95
Temperature mode	459.8	599.8
Appearance of the machine	377.9	509.8

(in view of influence of each ergonomic factor) under the formula [12-14].

The results of inspection are given in Table 4. As it is visible, by results of social inspection, there is a flexible enough device of an expert estimation of an available level of engineering for concrete objects and large reserves by way of perfection of modern machine in aspect of ecology, ergonomics and design [12-14].

CONCLUSION

The method allows objectively to define weight for each factor of the equipment technical imperfection, in order to allocate the main directions and tendencies of modification. However, it is impossible to improve the most essential, parameter in damage and all problems of designing needed to be decided in a complex with the use of computer designing methods and providing the maximum automation. Therefore, the heavy machine tool has turned to be comfortable work for the operators at the display of the computer managing technological process.

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