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Development of Ecological Criteria of Noise Control With Application of Absorbents

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Abstract: The operation conditions of the industrial equipment, acoustic parameters essentially depend on type of the sound field (free, diffuse or mixed). Besides the effect of the noise control of the machine itself, the field type also important, which in turn depends on the degree and quality of acoustic preparation of the workshop. The criteria is an estimation of applicability broadband absorbents, found during the current analyses, which enable to solve the problem related to the ecology of noise control at various manufacturing processes.

Key words: Ecological Criteria, Noise Control, Sound Field, Absorbent, New Materials

INTRODUCTION

The rational acoustic preparation of the industrial premises with absorbents allows effectively to correct the equipment's noise character. The objectives are to muffle voice-frequency, shock and impulse peaks in a spectrum, in order to provide acoustical masking for a broadband noise at the expense of primary high-frequency sound absorption in 2-3 neighboring octaves and to change the diffuse field for free one. It is not recommended to avoid the deterioration of an acoustical mode in the following cases:

* At a broadband noise spectrum: broadband noise absorbents are applied (vario-effective for all range of muffled frequencies);
* At broadband noise with a prevalence of high-frequency components in spectrum: mid and low-frequency sound absorbents are applied (except of high-frequency ones);
* In voice-frequency noise spectrum, impulse or shock peaks: sound absorbents are applied, which are not calibrated for such components, i.e., it is required to provide a narrow-band sound absorption for the frequencies. There is a given component and broadband sound absorption, if high and mid at frequencies, the above components are observed to exceed the allowable norms [1-5].

Sound Absorption and Adsorbents: The sound absorption in a porous and elastic material is connected with the dissipation in the dispersing environment. For example, in porous layer, on an elastic membrane or in a hollow gas volume with the elements of springy viscous losses the, factor of sound absorption, accordingly is defined by the relation of the absorbed energy to the falling one. The mechanism of sound absorption at a level of resonance of micro and macro systems is distinguished in comparison with length of sound wave [3, 6].

The mechanism of sound absorption in porous layer takes place at micro resonance processes at the expense of viscous friction and elastic deformation of an air in pores, and deform the skeleton and the boundary layers of capillaries. The reciprocating movement of an air in pores, caused by variable sound pressure from falling wave, results in deformation of all oscillatory system of structure of porous layer, causing cyclic change of gradients of temperatures, diffusion of thermal flows and the dispersion of an energy. The share of thermal losses attains 40%. It was considered, that the basic losses are of elastic viscous character, however it became known, that in light weight layers with fibers of less thickness than 1 micron, the losses can take place at a resonance of a skeleton at frequencies below 100 Hz.

For defining the acoustic characteristics of porous materials, it is necessary to know three parameters: thickness (m); density ρ (kg/m^3) and flow specific resistance measured in (10^3 N/m^4) [5-10]. Another important parameter is the average diameter of fiber and structural factor. The porous material is characterized also by the effective density and module of compression (elasticity) of an air in pores.

In ISO standards, the classification concepts of efficiency of absorbents for low, average and high frequencies, related to first, second and third class. Information on typical and standard absorbents efficiency are given [9-14].

Single layer absorbents are the most widely used, and manufactured in various forms, and also as plasters and coverings. The basic is porous, fibrous or granular material with banding or without, and also as foamed masse with through pores. The manufactured slabs are of the modular sizes (300 x 300 and 900 x 1000 mm) and of 15-100 mm thickness. Whereas, the density ranges from 50-250 kg/m^3 and the sound absorption factor varies from 0.6–0.9 for high and mid frequencies. The single layer absorbents are also made in rolls and sheets of organic and inorganic fibers, covered with protective synthetic films or fiberglass fabric [15-17].

The opportunities of expanding the range working of absorbents capturing more low frequencies are investigated, as the absorption for high frequencies is the direct function of thickness of porous sheet. It is offered to make finer punching in covering sheet and to apply laminated thick layers of frictional materials. Effective absorbents can be made by combination of many effects: resonator, membrane, dissipative.

At an estimation of efficiency of absorbents in conditions of industrial premises, it is necessary to take into account the geometry of the premises, the character of a sound field-free, diffusion or mixed and the method of placing the absorbent. As a result of correct method of placing the absorbent the effects of noise control attain 3-15 dB, depending on the distance from the direct source. There are three kinds of absorbents, i.e., flat, volumetric and screen depending on spatial position.

The flat absorbents are most widespread and made of various types of porous-fibrous, cast punched materials. The sound absorption maximal effect is 0.8 – 0.9 with an average of 0.5. Volumetric absorbents have more sound absorption. They are manufactured in any form from various materials. The efficiency of volumetric absorbents surpasses by 50-70% in comparison with flat absorbents. However, the former has not found wide applications in various enterprises because its fire danger stipulated by the increased dust content.

The important stress should be made on wider application of sound-proof structures, in particular, for internal processing of sound isolating casings, outside processing of acoustic screens, as layers of sound isolating structures, that strengthens sound absorption near sources of noise of the equipment, and sometimes in the equipment itself. At the same time, the presence of an absorbent, as a passive method of noise control, does not affect negatively the technological processes. Economically it is most expedient to apply environment friendly absorbents of industrial waste, which by the efficiency are not worse than standard ones, but much cheaper.

Ecological Criteria of Noise Control : The ecology of noise control is a component of general ecosystem. There are sanitary norms, spectral dependencies of harmful influence of noise on human organism. General criteria of the ecology of noise control, coordinating all aspects of the problem, including parameters of noise control itself are not developed however.

Taking into account the spectral structure of sound oscillations, radiated by the equipment, the spectra of industrial noise can be divided into six categories. Besides of the direct harmful influence on a man from sanitation and hygiene point of view, the high levels of noise exert direct aggravating influence on the technological process, when the personnel becomes not capable to operate the equipment satisfactorily.

VI Category: Level of sound or sound pressure in a particular octave exceeds 110 dB, probability of damage of hearing is more than 0.5 (dangerous and inadmissible mode);

V Category: Level of sound or sound pressure is in an octave of 100–110 dB, the probability of a damage of a hearing is 0.25–0.5 (inadmissible mode);

IV Category: Parameters of noise, when,

$$\{N_{Ls} \rightarrow L_{(n-1)}\} \geq \{N_{n,,} \rightarrow L_{(n)}\} \geq \{N_{Ls} \rightarrow L_{(n+1)}\} \qquad (1)$$

for all n from 7 up to 12, and $L_A \leq L_{Anorm} + 15$ dBA,

$$\{N_{Ls} \rightarrow L_{(n=6)}\} > N_{Lsnorm} \qquad (2)$$

where, N_{Ls} is the norms the number of limiting spectrum on data ISO, norm, $L_{(n)}$ is the measured or calculated levels of sound pressure in the standard octave bands of frequencies of serial number n=6-13 (from expression. F_{mh} = 2 Hz, $L_{(n+1)Anorm}$ is the noise level (dB) in the relevant single band number, the integral normative sound level (dBA), n_e is the number of a an extreme spectrum of the aggregate of standard curves $L_{Ls}{}^N$, N_{Lsnorm} is the number of the extreme spectrum meeting the allowable norms and $\{N_{Ls} \rightarrow L_{(n)}\}$ is the number of the extreme spectrum corresponding to the measured or calculated value. Under these conditions acoustic situation is as much as possible close to the normative requirement and to name a mode could be called as extreme admitted.

III Category: Working conditions, at which the requirement met the norms, i.e.,

$$\{N_{Ls} \rightarrow L_{(n)}\} = N_{Lsnorm} \qquad (3)$$

mode can be called as normative.

II Category: Industrial conditions when

$$\{N_{Ls} \rightarrow L_{(n=6)}\} \leq N_{Lsnorv} \qquad (4)$$

At which the most favorable acoustical mode is insured and in addition to the requirements (2) and (3) the diffusion field is absent in an industrial premise. For the operator the opportunity of acoustic diagnostics–the control of the operation of the equipment by hearing is added (acoustical adaptation, the localization of sources of noise, opportunity of speech communication without a tension of a voice and a hearing). The given mode is possible to call favorable.

I Category: conditions at which the restrictions (3) and (4) are observed and the level of a sound does not exceed 50 dBA ; comfortable acoustical mode.

For industrial premises it is possible to ensure the optimum parameters of sound absorption for the most general case. The value of required average factor of sound absorption necessary for normalization of an acoustical mode, can be determined from the formula for the reflected field

$$\Delta L_{(n)} = 10\lg\frac{\bar{\alpha}'_{(n)}}{\bar{\alpha}_n}\ \text{dB} \tag{5}$$

where, $\bar{\alpha}_{(n)}$ & $\bar{\alpha}'_{(n)}$ are the average factors of sound absorption before and after the acoustic processing, or

$$\Delta L_{(n)} = L_{meas\ (n)} - L_{Ls\ (n)}^{N_{\max}} \tag{6}$$

where, $\Delta L_{(n)}$ is the excess of the measured levels of sound pressure beyond the extreme spectrum typical for II category of the industrial noise mode at $N_{Ls\max}$, that is

$$\bar{\alpha} = \frac{\sum_{i=1}^{r}\alpha_i S_i}{\sum_{i=1}^{r} S_i};\quad \bar{\alpha}' = \frac{\sum_{i=1}^{r}\alpha_1' S_i}{\sum_{i=1}^{r} S_i} \tag{7}$$

where, S_i is the area acoustically homogeneous site number i of internal partitions in a shop, and α_i is the average factor of sound absorption of building materials and structures (is defined by reference tables). The value of required for (p) sites factor of $\bar{\alpha}'^{(p)}$ of absorbents (if for facing are used only (p) of sites, for example, the ceiling and walls) is defined under the formula:

$$\bar{\alpha}'^{(p)} = \frac{\bar{\alpha}'\sum_{i=1}^{r} S_i - \sum_{i=1}^{r}\alpha_i^{(r-p)}S_i^{(r-p)}}{\sum_{i=1}^{r} S_i^{(p)}} = \frac{\sum_{i=1}^{r}\alpha_i^{(p)}S_i^{(p)}}{\sum_{i=1}^{r} S_i^{(p)}} \tag{8}$$

where, r and p are indexes number of conditional devices the plans and walls of subjects to ultrasonic handling, the index (p) means that the summation is realized only for (p) sites, and index (r-p) is for rests. The value of $\bar{\alpha}_n'^{(p)}$ is calculated for each octave band of N_n, where n=6-13. Using (8), it is possible to compose the formula for calculation of the spectrum corresponding to the measured level of sound pressure in octave band of n = 6:

$$N_{n,,\max} = \{N_{Ls} \rightarrow N_{(n-6)v}\} \tag{9}$$

Function $\Delta L_{(n)}$ and (9) have single maximum at $n=n_{\max}$

$$\Delta L_{\max} = L_{\max} - L_{H\div} \tag{10}$$

where, ΔL is the difference of noise levels before and after noiseless (effect), dB, $L_{\max} = L_{mesur}$ ($n=n_{\max}$) and $L_{\div} = L_{Ls}^{mesur}$ ($n=n_{\max}$).

The character of the changing of the function $\Delta L_{(n)}$ in (10) looks as a rule like exponential curve. It allows considering with sufficient approximation, that the function $\Delta L_{(n)}$ changes under the law

$$\Delta L_{(n)} = \left(L_{\max} - L_{H\div}\right)\left[1-\left(\frac{n-n_{\max}}{n_{\max}-6}\right)^2\right] \tag{11}$$

If $6 \le n \le 13$.

Thus, at calculations of sound-absorbing structures made of waste for the majority of industrial shops (where the broadband noise prevails) the next formula is suitable:

$$\bar{\alpha}' = \bar{\alpha}_{(n)} \cdot 10^{0,1\left(L_{\max}-L_{H}\right)\left[1-\left(\frac{n-n_{\max}}{n_{\max}-6}\right)^2\right]} \tag{12}$$

And according to (12)

$$\bar{\alpha}'^{(p)}_{\max} = \frac{\bar{\alpha}\left(n_{\max}\cdot S\cdot 10^{0,1\left(L_{\max}-L_{H\div}\right)-(r-p)} - \alpha_{(n)\max}\cdot S^{(r-p)}\right)}{S - S^{(r-p)}} \tag{13}$$

where, $S=\sum_{i=1}^{r} S_i$ is the area of the internal surfaces of a premise (m^2), $S^{(r-p)}=\sum_{i=1}^{r} S_i^{(r-p)}$ the area of internal surfaces of a premise, which are not subject to acoustic processing (m^2), $\bar{\alpha}_{(n)\max}^{(r-p)}$ is the average over a surface S(r-p) factor of sound absorption in the octave band of $n=n_{\max}$, and $\bar{\alpha}_{(n)\max}$ is the average over on a surface S factor of sound absorption in octave band of $n=n_{\max}$ for no acoustically processed premises (reference data).

According to corrected function (10), it is possible to construct functions for the typical frequency characteristics of the factors of sound absorption for the majority of branch manufactures. It is possible to note, that the curve looks like the turned upside down spectrum with an extremum beginning from the maximal level that is the optimum for the effect of audio masking. It is known that human ear perceives low and mid frequency sounds less painful.

CONCLUSION

Depending on n and $\alpha'^{(p)}_{\max}$ for a given premise and production the absorbents, based on various principles can be applied. For example, for compressor room-low frequency, for ventilating chambers–mid frequency ones. But most general case is broadband absorbents of mainly mid and high-frequency sound absorption. Such the absorbents are necessary in the majority industrial premises [5-8].

Thus, the criteria, is an estimation of applicability broadband absorbents, found during the analysis, enable to solve the problem of ecology of noise control of various manufactures. Using all purpose absorbents and applying simple enough criteria given in present article, the designer, knowing only typical spectra of noise of a productions can, without additional complication, choose the suitable type of absorbents, which will allow to correct optimally character of a sound field and to ensure real effect of noise control by means of one passive method (acoustic processing of a shop) without intervention in the equipment [9-14].

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