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Regional reduction of ecoacoustics related noise pollution

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Abstract

The article deals with a theoretical overview of the new field of acoustics – the ecoacoustics – and its relations to the general problems of environment and acoustics (sonic vibrations and other phenomena). General solutions regarding improvement of our environment are by reducing the negative impact of physical and other pollutants on living beings and nature. With regard to the said needs methods of ecoacoustics development and measures for normalising acoustic parameters are investigated.

The paper investigates solutions related to the impact of vibrations and their emissions by different known sources as well as methods for reduction of negative impact of the vibrations.

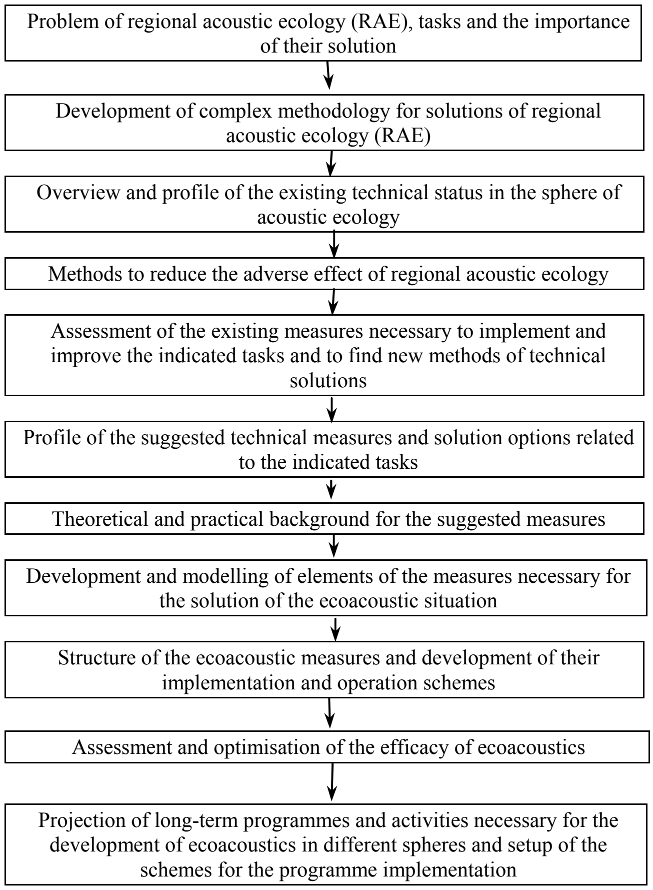
Introduction

Acoustics as a science diverged from the science of physics during the last century and expanded owing to positive and negative phenomena. Acoustics contributed to the scientific investigations that resulted in their wide application in engineering and human life. However, specific factors, such as intensive vibration, noise and infrasonic waves influence our health and environment. The observed acoustics phenomena of resulted in the split of this science into many spheres, including among others, appearance of the independent key research spheres, such as vibro – acoustics, ultrasonics, physiological acoustics, electro acoustics, hydro acoustics, architectural, atmosphere, music and construction acoustics, etc.

Development of engineering sciences resulted in the affluence of different mechanisms and machinery that filled human life and nature – the environment of all living beings. This contributed to the formation of environment protection from physical pollution as a sphere of ecosystem protection the latter being a constituent of the ecology science. This led to a gradual formation of independent sphere of science – protection from acoustic pollution, such as vibration, noise, ultrasonic waves and other detrimental acoustic factors.

Ecoacoustics can be defined as a field of science investigating the relations of organic and non-organic nature with the acoustics. Acoustic parameters can have different impact. The impact can be both positive and negative. The paper deals with the negative impact of the acoustic parameters on the environment and the methods of protection from such impact.

In order to explore the importance of ecoacoustics in our life it is necessary to assess the acoustic pollution of our environment and to give a scientific (both theoretical and practical) background for activities related to the solution of the problems that are so urgent to the public. The activity should not start from the zero. It is necessary to analyse all existing research methodologies applied in the sphere of acoustics and ecology worldwide. As it was said above [1], the solutions of the problem will differ with regard to the geographical location of the investigated region, types and development level of the technique and methodologies used. A scheme given below may serve as guidance for the solution of the relevant problems both in our region and in other Baltic countries.



Physical pollution (vibration and noise) of the environment in the region

Even though regional problems mostly coincide with global, their geographical location and technologies applied determine variations of the problems and the methods of their solving. Lithuania can be attributed to the common region of Baltic countries; therefore they share the same concern regarding reduction of environmental pollution.

Vibrations emitted by the source and their impact on environment

Advanced technologies and equipment penetrated even remote outskirts of nature. Vibration and noise can be emitted from different sources, such as power grid unit substations, compressor houses, vibration equipment used in production of construction materials and other mechanisms of advanced technology.

Owing to a high intensity of dynamic activity of major volumes in the labour process the vibrations emitted to the environment invoke not only vibrations that radiate through structures and soil, but also producea noise. Vibrations of low frequency and high intensity radiate through soil and building structures and in that environment invoke infrasonic waves. Infrasonic waves are as harmful as audible sound waves, i.e. noise. The infrasonic waves must be investigated more closely and standards of their allowed intensity must be defined.

As an example, some operated air compressors emit vibrations ranging from 2 to 12 Hz and invoke a general sound pressure level by 110 dB and more. Here sound pressure levels reach 73 – 75 dB (A). At a distance of 100 – 150 metres from residential buildings sound pressure levels as a rule range from 80 to 100 dB. Motor vehicles in operation emit similar vibrations.

Scientists investigating the effect of infrasonic waves on a human health have established that the sound pressure level up to 90 dB does not lead to complaints on the side of residents, however laboratory investigations revealed the following facts [2, 3].

Investigation was carried out in the infrasonic field of intensity 110, 100 and 90 dB at frequencies 4, 6, 8, 12 and 16 Hz. Infrasound at frequencies of 6 and 12 Hz with the intensity of 110 dB at 15-minute exposition causes statistically valid changes on the part of the central nervous and cardiovascular system; the short-term effect of infrasound at frequencies of 4, 8 and 16 Hz impacted the central nervous system of those under study, causing the prolongation of the latent period of reflecting reactions on the sound and disorder of power relations, which were also preserved in the rehabilitation period. Those under subjective observation noted some pressure in the sinciput area and the inhibited condition (were drowsy). Change in some other indicators totally in the group was not trustworthy.

Thus, a level of 110 dB even at the short-term exposition should be considered to be as acting.

Infrasound at a level of 100 dB also had an effect on the central nervous system, however, some difference was observed in its response reaction in dependence on the frequency: more expressed at the frequency 16 Hz and less expressed at the frequency 4 Hz. Other physiological indicators were without the substantial changes. Consequently, the level of 100 dB may be considered as a threshold one.

Further we shall study how vibrations from our selected object of exploration, i.e. from a vibromachine for manufacture of construction blocks in the city of Šiauliai are propagating.

Vibrations of the foundations of a vibromachine excite the vibrations of the ground massive on which it is erected. Since the ground has the properties of the elastic medium, the vibrations in the form of waves propagate to all sides from the foundations to considerable distances, reaching 500–1000 m. Buildings and structures, located in the zone of propagation of those waves, are subject to vibrations. Vibrations may be dangerous, having an effect on the durability of buildings and structures, or harmfully affecting people and equipment. In these cases it is necessary to take special measures for prevention of impermissible vibrations and for elimination of vibrations of the already existing objects. For a correct selection of such measures it is necessary to have an understanding about the character of impact of those waves on the objects, and the forms and parameters of vibrations of buildings and structures.

As a calculation model of the phenomenon of elastic waves in a ground, the elastic isotropic half-space, into which the vibrating mechanism with the flat foundation of rectangular form was impressed, was selected. Two types of waves propagate from the vibrating mechanism independently of one another: waves, in the presence of which the ground experiences only a relative change in the volume, or waves of compression and extension, and waves, in the presence of which the ground particles just experience the relative displacement, or shear waves. The former are called longitudinal, since the ground particles during the propagation of such waves are displaced in parallel to the direction of wave propagation (along the radial straight line from the source). The latter are called transversal, since the displacement of the ground occurs perpendicularly to the propagation of a wave.

Relationship between velocities c_1 and c_2 of the propagation of the former and latter waves is given by an expression:

$$\frac{c_1}{c_2} = \sqrt{\frac{2(1-\mu)}{1-2\mu}},$$

here μ is the Poisson coefficient.

In all cases the relation $c_1 / c_2 > 1$, consequently, the longitudinal waves propagate with the higher velocity than the transversal waves. Numerical values of the velocities of longitudinal and transversal waves in different grounds [4] are given in the table.

Ground	Wave propagation velocity, m/sec	
	c_1	c_2
Humid clay	1500	150
Loess of natural humidity	800	260
Solid gravel-sandy ground	480	250
Sand:		
- Finely granulated	300	110
- Medium granulated	550	160
Medium-sized gravel	760	180

In addition to longitudinal and transversal waves, one more type of waves appears on the surface of the ground – surface waves, penetrating the ground not deeply. The foundations of the vibrating mechanism under study are the sources of wave excitation in the ground, and the foundations of buildings and structures, the receivers of waves, are situated close to the surface of the ground. Therefore the surface waves are of special interest for us. Longitudinal and transversal waves are propagating in three dimensions, whereas surface waves only in two dimensions, and already at a comparatively small distance from the source they prevail over longitudinal and transversal waves, since the relative energy of the surface waves diminishes in proportion to the distance from the source, and that of longitudinal and transversal waves in proportion to the square of the distance.

The velocity c_3 of a surface wave is somewhat lower than the velocity of transversal waves c_2. Thus, at $\mu = 0.25 \div 0.5$; $c_3 = (0.92 \div 0.95)\, c_2$. The frequency of the vibrations of the ground, propagating from the foundations of the operating machine by surface waves is equal to the frequency of the vibrations of the foundations.

The wave length of the surface waves $L = c_3 / f$, of propagating from the foundations in the different media of the ground is within the range of 17 to 63 m.

Amplitudes of vertical and horizontal components of the ground vibrations decrease with the increase of the depth, but at small depths (within the limits 0.2–0.5 of the wave length) they change comparatively insignificantly. This circumstance is of a practical importance. Since the amplitudes of the ground vibrations from the surface waves propagating from the foundations at the depth of 8–30 m practically do not change, there is no sense for the purpose of decreasing the amplitudes of vibrations to increase the depth of laying of the foundations of buildings and structures – receivers of waves. Nor there is necessity to lay the foundations at the depth lower than the foundations of the closest structures (walls, columns).

Amplitudes of the ground vibrations decrease depending on the distance of the source of vibrations. Vibrations are less intensive in the direct approximation to the source of attenuation of vibrations than at large distances from the source. Therefore, in practical computations, the amplitudes of the ground vibrations close to the foundation in the circle of radius r_o, equalling the greatest value of the base of the foundation, are taken as a constant and equal amplitudes of vibrations of the foundation, and at great distances are determined by a formula

$$A_r = A_0 \sqrt{\frac{r_0}{r}} \cdot e^{-\alpha(r - r_0)}, \qquad (1)$$

where A_r, A_o are the amplitudes of the ground vibrations at a given distance from the source; α is the rate of attenuation, the value of which fluctuates for different grounds from 0.03 to 0.1 m^{-1}.

Under other similar conditions the frozen grounds have lower values of the attenuation α. Consequently, the waves of the vibrating mechanism in the winter propagate longer distances than in the summer.

This theoretical statement was confirmed by our experiments performed in a specific object.

The ways for reduction of vibrations

Many methods and ways of reduction of the intensity of the parameters of vibrations exist. They are applied taking into consideration the type of the source of vibrations, its specifications and destination. For reduction of the intensity of the source of vibrations under exploration, it is possible to apply the following more important methods from those of numerously existing. Namely, that is reduction of vibrations at the source of their onset, on the way of propagation, and increasing the distance from the source and the object protected from the impact of vibrations. Let us touch in brief the essence of these methods and the opportunities for their application in the case of our exploration.

Reduction of vibrations at the source of their onset

The most effective way for reduction of impact of vibrations on the environment is to apply all methods for reduction of vibrations of the mechanism or the machine foreseen at the stage of its design. Such methods may include selection of materials according to their vibroacoustic properties, rational selection of directions of rotations and movements, reduction or change of the processes of impacts, selection of the machine or mechanism parts with a high rate of internal friction of the material or damping of the mechanical vibrations of those parts, balancing of rotating parts and many others.

However, it is necessary to state that the above indicated and still not indicated ways for reduction of vibrations by the pointed out method are not always and not everywhere applicable. In the case of our investigation, a vibromachine must excite the vibrations of the required intensity of the working part of the mechanism, which are necessary for the fulfilment of the preset working process. Therefore, in this case attention shall be concentrated on the bearing part, where the vibrating mechanism is fixed by way of damping and insulation.

In all cases the ways applied for reduction of vibrations of the working mechanism (machine) shall be based on calculations, which should be based on the evaluation of the possible sources of vibrations and their propagation in the mechanism.

Reduction of parameters of vibrations on the way of propagation

Vibrations of our machine under study through the parts (frames) of reinforcement into the foundations propagate further into the environment and give rise to the undesirable phenomena that have been already mentioned.

For reduction of the amplitudes of vibrations of the foundation under the machine, it is necessary to seek that frequencies of natural vibrations of the foundation together with the vibroplatform fixed on it could differ as much as possible from the frequency of excitation. It is desirable that frequencies of natural vibrations of the foundation with the machine fixed on it could be higher or lower the frequency of excitation by not less than 30 %.

In the case when the operating frequency of the machine is lower than the lowest frequency of natural vibrations of the foundation with the vibromachine fixed on it, for reduction of the vibrations of the foundation it is necessary to increase the coefficient of rigidity of the base of the foundation with a view that the frequency of natural vibrations of the foundation gets increased.

Increase in the coefficient of rigidity of the base of the foundation is achieved by expanding its base or installing the plate, connected rigidly to the foundation, by strengthening the basis with the help of piles, as well as by the chemical reinforcement of the ground, cementation, bituminization, etc.

Reduction of the horizontal vibrations of the foundation under the machine may be also achieved by way of the hinge joint of the massive concrete plate to the foundation, located near the foundation on the upper layer of the ground (Fig. 1). The hinge joint of the plate eliminates the harmful effect of the possible difference of the sinking of the foundation and the plate. With such arrangement, horizontal vibrations of the foundation should cause the horizontal displacements of the plate in the ground, this being accompanied by the increase in the elastic forces and attenuation in the system. One of the advantages of this method is the possibility of taking out of the plate outside the walls of the building.

The dimensions of the plate are selected by calculation; simultaneously, the effect of attenuation of vibrations may be increased also after the installation of the plate by way of its building up.

It is recommended to slect thickness of the plate in dependence on the power of the structure and the dimensions of its foundation as equalling 0.4–0.8 *m*.

The area of the base of the plate F_1, connected to the foundation, should be no less than specified according to the formula [4]:

$$F_1 = \frac{C_x^{o}(n-1)F}{C_x(1+A-B)}. \quad (2)$$

Here

$$A = \frac{C_x^{o} F h^2}{C_\varphi^{o} I}; \quad B = \frac{n\left(\frac{H}{h}-1\right)}{\frac{H}{h}+\frac{C_\varphi^{o} I}{C_x^{o} F h^2}},$$

here *n*– is the number showing how many times the amplitude of vibrations of the foundation reduces with regard to the connection of the plate; value *n* is taken not more than 4; C_x^{o} and $C_\varphi^{o} C$ are the values of the coefficients C_x (elastic uniform displacement) and C_φ (elastic non-uniform compression) of the base of the existing foundation, obtained by experimentally; C_x is the value of the coefficient of the elastic uniform displacement, taken according to Eq. 3; *F* is the area of the base of the foundation; *I* is the moment of inertia of the area of the base of the foundation in respect to the axis, running through the centre of gravity of its area of the base and perpendicularly to the plane of vibrations.

The calculated values of the coefficients of elastic non-uniform compression C_φ and of elastic uniform displacement C_x are taken as equal

$$C_\varphi = 2C_z, \quad C_x = 0,7C_z. \quad (3)$$

C_z is the calculation value of the coefficient of elastic uniform compression for natural foundations, determined when investigating the ground; designations *H* and *h* are given in Fig. 1.

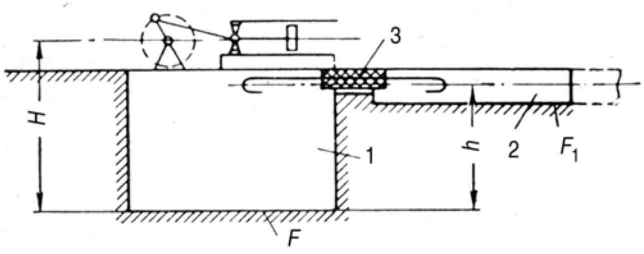


Fig. 1. **Diagram of the foundation with the hinge-joined massive plate: 1 – foundation; 2 – plate; 3 – swivel link**

When the operating frequency of the crusher is higher than the maximum frequency of natural vibrations, it is possible to obtain the reduction of the amplitudes of vibration of the plant by increasing the mass and the moment of inertia so that the frequency of natural vibrations becomes decreased.

Reduction in the degree of transmission of vibrations to the buildings and structures from the operation of the machine may be achieved by the plant along the entire perimeter of the foundation under the crusher of the sufficient clearance, separating the foundation of the machine from the adjacent constructions (for example, floors or foundations of the buildings).

In practice, cases of emergence of the increased vibrations of separate elements of the foundations itself occur. Reduction in the vibrations of the elements of the foundation is reached by changing their mass or rigidity, provided that natural frequencies of the elements differ from the operating frequency of the machine no less than by 1.5 times.

Impact of the distance on the source inducing vibrations

As already mentioned, impact of vibrations of high amplitudes propagating in the ground may reach the distance of up to 1000 *m* from the source.

The influence of that impact depends on the ground and other already mentioned properties. Therefore when building plants it is necessary to know in advance the vibroacoustic properties of mechanisms and machines as well as vibroacoustic characteristics of technological processes, according to which it would be possible to decide about the detrimental effect of vibrations and noise at the determined distance.

Conclusions

1. Ecoacoustics is one of the newest fields of general acoustics and the science it forms is applied for tackling problems of the pollution of the surrounding environment.
2. A diagram of works for solution of the necessary problems of the regional acoustical ecology, which

offers the opportunity for making long-term plans, is given in the work.

3. When exploring and analyzing the harmful parameters of ecoacoustics, attention was focused on vibrations invoking inaudible noise – infrasound.
4. The results of experiments conducted by other sources are presented. They show convincingly the detrimental effect of infrasound. While analyzing this statement, a problem is put forward how to reduce the impact of infrasound to the environment and human organism.
5. It was established that the sources of infrasound excitation are the operating machines and mechanisms, propagating vibrations of increased intensity to an environment.
6. In analyzing the propagation of vibrations in the ground, it was determined that low-frequency vibrations may propagate very far, even up to 1000 metres.
7. It was established that the amplitude of propagating vibrations depends on the attenuation coefficient, which varies with different grounds.
8. Not taking into account the variety of the ground, it is defined that the frozen ground is more permeable to vibrations and their amplitude attenuates less with the distance, therefore the intensity of vibration parameters at the same point in the winter increases.
9. For reduction of the intensity of vibrations as the parameters of the impact on environmental pollution, the main measures are foreseen, namely their reduction in the source, on the way of propagation and increasing the distance of the objects under protection from sources of vibrations.

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Akustinės ekologijos taršos mažinimas regione

Reziumė

Pateikta teorinė akustinės ekologijos apžvalga ir apratos šios naujos akustikos srities ryšys su gamtos apsaugos ir akustikos (triukšmo vibracijų ir kt. reiškinių) bendrosiomis problemomis. Numatomi bendri sprendimai, kaip pagerinti mūsų aplinką ir sumažinti fizikinių bei kitų teršalų daromą žalą žmonėms, gamtai ir gyvūnijai. Tyrinėjami akustinės ekologijos plėtros būdai ir akustinių parametrų normalizavimo, atsižvelgiant į minėtus poreikius, priemonės.

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