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REGULAR ARTICLE

Dependence of the Dynamic Mechanical and Acoustic Properties of the "Transducer - Electroelastic Screen" System on the Frequency of Electrical Excitation of the Screen

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The solution to the problem of the multi-functionality of acoustic location devices is connected with creating opportunities for operational management of the characteristics of their acoustic systems. For this, their acoustic screens must be made in electroelastic bodies. For a typical element of such a system, consisting of a transducer and an electroelastic acoustic screen, the problem of determining analytical ratios describing the mechanical, acoustic, and electric fields of this element is solved by coupled fields in multi-coupled regions. At the same time, the mutual connection of acoustic fields during their formation, the mutual influence of energy transformation and formation processes, the influence of the process of operational management of the characteristics of the electroelastic acoustic screen, and the reaction of the surrounding medium to the excitation of acoustic waves in them are taken into account. As a result of the analysis of the results of the numerical experiment for the construction options of a typical element with the same and different frequencies of the main resonances of the transducer and the screen, the dependence of the mechanical and acoustic dynamic properties of the element during the operational change of the screen characteristics was established and compared. The regularities of these properties for different frequency ranges are determined, and their physical justification is given.

Keywords: Element "transducer-electroelastic screen", Operational management, Mechanical field, Dynamic properties, Active acoustic screen, Mechanical fields.

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1. INTRODUCTION

The main direction of developing modern acoustic location devices is to ensure their multifunctionality [1, 2]. She determines the need to manage the parameters of the elements included in these devices. Such parameters include directional properties, frequency dependence, radiated acoustic power, etc.

The existing methods of managing these parameters are conditionally divided into passive and active. One of the most widespread passive methods is the use of various types of acoustic screens. They can be made of acoustically soft or acoustically hard materials, in which $\rho_m c_m$ (where ρ_m and c_m are the density and speed of sound propagation in the material, respectively), will be, respectively, smaller or greater than $\rho_0 c_0$ of the working environment in which they work [3]. Screens with intermediate values between soft and hard are called impedance screens. The main disadvantage of passive acoustic screens is the impossibility of operational management of their parameters during the operation of the devices [4-8].

The way out of this situation is to switch to active methods. These include methods of controlling the parameters of location devices and their acoustic screens from the electrical side [9, 10]. Their main advantage is the possibility of operational control during the operation of such devices. An acoustic screen made in the form of an electroelastic body, for example, made of piezoceramic material, has this possibility. As is known from [11], depending on the selected frequency range of its frequency characteristic, the acoustic properties of an electroelastic body correspond to the properties of acoustically soft, acoustically rigid, or impedance acoustic screens, thus covering the entire set of properties of passive screens.

At the same time, as part of the location device, electroelastic acoustic screens perform two functions – the function of energy conversion and the function of its formation. Each of them has its characteristics [8-10]. When energy is transformed in piezoceramic media, there is a mutual connection between physical fields – electric, mechanical, and acoustic [12]. During the formation of energy due to the multiple exchanges of radiated and reflected sound waves between the elements of the devices, the interaction of the acoustic fields of these elements occurs [7]. And, finally, since acoustic fields are present in energy transformation and

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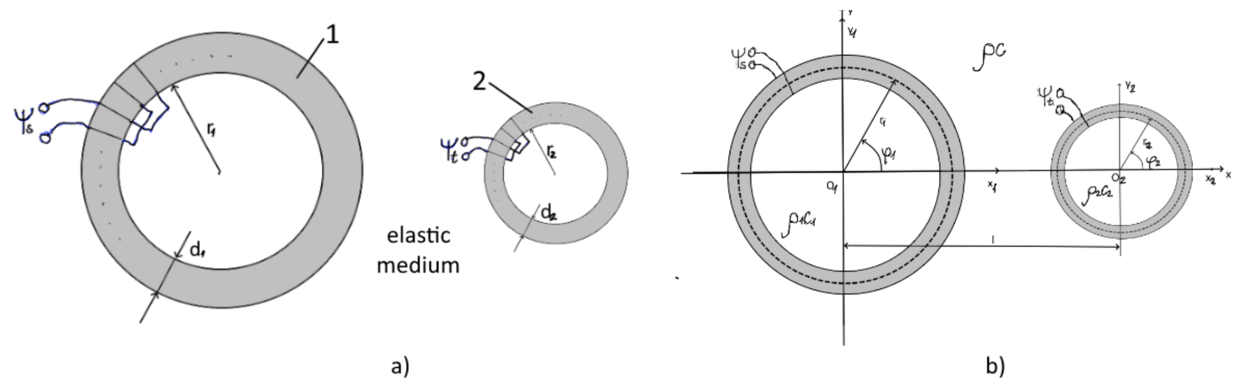

Fig. 1 – Acoustic location device a) – physical model; b) – calculation model

its formation, there is also a mutual connection between these processes [7].

Let's consider that a typical element of most acoustic antenna designs is the "converter – acoustic screen" system [1, 2, 8]. Then, the work aims to determine the dynamic properties of the "transducer – electroelastic screen" system under the operational control of screen parameters and the connection of fields and processes in the system.

2. STATEMENT OF THE PROBLEM AND ITS SOLUTION

Consider the acoustic location device, the cross-section of the physical model shown in **Fig. 1**a. The device consists of a cylindrical acoustic screen 1 and a cylindrical piezo transducer 2. Their longitudinal axes are parallel and placed at a distance of l. Acoustic screen 1 is a p/c (piezoceramic) shell with an average radius r_1 and thickness d_1. The shell can be continuous or sectioned. Its internal cavity can be vacuumed or filled with gas or liquid. Shell 1 is excited by the electrical voltage Ψ_e.

Piezo transducer 2 is a continuous or sectioned structure with an average radius r_2 and thickness d_2, vacuumed, filled with gas or liquid. Transducer 2 is excited by the electrical voltage Ψ_n. The location device is placed in an elastic environment.

The calculation model (**Fig. 1**b) is a system of parallel circular cylinders placed in the general Cartesian coordinate system $0xyz$. Local Cartesian and circular cylindrical coordinate systems are associated with each of the cylinders.

As shown above, the physical feature of the acoustic location device is the presence of three types of interactions during its operation – two types of interactions of physical fields during the implementation of energy transformation and formation processes and one type of interaction of these processes themselves.

Mathematically, these interactions of physical fields and processes can be taken into account by jointly solving the system of the following differential equations:

- the Helmholtz equation, which describes the movement of media inside the screen and the emitter and outside them:

$$\Delta\Phi_{ns}+k_{ns}\Phi_{ns}=0, \quad s=1,2;\ n=1,2;$$

- equation of motion of the thin p/c shells of the screen and the emitter with circular polarisation (for sectional versions) in displacements:

$$\begin{aligned}&(1+\beta_s)\frac{\partial^2 u_s}{\partial\varphi_s^2}+\frac{\partial w_s}{\partial\varphi_s}-\beta_s\frac{\partial^2 w_s}{\partial\varphi_s^2}=d_s\gamma_s\frac{\partial^2 u_s}{\partial t^2},\\&-\frac{\partial u_s}{\partial\varphi_s}+\beta_s\left(\frac{\partial^3 u_s}{\partial\varphi_s^3}-\frac{\partial^4 w_s}{\partial\varphi_s^4}\right)-w_s+\frac{e_{33s}}{C^E_{33s}}r_{0s}E_s+\frac{\alpha_s}{h_s}q_{rs}=\alpha_s\gamma_s\frac{\partial^2 w_s}{\partial t^2},\end{aligned}\qquad s=1,2; \tag{1}$$

- equations of forced electrostatics for piezoceramics:

$$\vec{E}_s=-grad\psi_s,\ div\vec{D}_s=0, \quad s=1,2.$$

Here Δ – the Laplace operator; Φ_{ns} – speed potential of the s- th element of the location system (inside $n=1$ and outside $n=2$); k_{ns} – wave numbers of media (k_{1s} inside and k outside the element); u_s and w_s – circumferential and radial components of the vector of displacements of the points of the middle surface of the shell of the s-th element; $\beta_s=\frac{h_s^2}{12r_{0s}^2}\left(1+\frac{e_{33s}^2}{C^E_{33s}\varepsilon^D_{33s}}\right)$; $\alpha_s=\frac{r_{0s}^2}{C^E_{33s}}$; q_{rs} – external load of the s-th element; C^E_{33s}, ε^D_{33s}, e_{33s}, γ_s – respectively, the modulus of elasticity at zero electric stress, the dielectric constant at zero strain, the piezo constant, and the density of the material of the s-th p/c shell.

The procedure for the simultaneous solution of the given system (1) of differential equations by the method of coupled fields in multi-connected domains is similar to that described in [7].

To do this, let's divide the entire area of existence of the physical fields of a typical element into several partial areas. Then, the kinematic and dynamic conjugation conditions of the internal Φ_{2s} and external $\Phi_1 = \sum_{s=1}^{2} \Phi_{1s}$ fields at the boundaries of the distribution of partial regions will have the form:

$$\begin{aligned}
&-\frac{\partial \Phi_{2s}\left(r_s,\varphi_s\right)}{\partial r_s} = \frac{\partial w_s}{\partial t},\ 0 \le \left|\varphi_s\right| \le \pi,\ r_s = r_{1s} - \frac{h_s}{2};\\
&-\frac{\partial \Phi_{1}\left(r_s,\varphi_s\right)}{\partial r_s} = \frac{\partial w_s}{\partial t},\ 0 \le \left|\varphi_s\right| \le \pi,\ r_s = r_{1s} + \frac{h_s}{2};\quad s = 1,2.\\
&q_{rs} = \rho_1 \frac{\partial \Phi_1}{\partial t} - \rho_{2s}\frac{\partial \Phi_{2s}}{\partial t},\ 0 \le \left|\varphi_s\right| \le \pi;
\end{aligned} \tag{2}$$

Mechanical u_s and w_s and acoustic Φ_{1s} and Φ_{2s} fields of the screen ($s = 1$) and transducer ($s = 2$) are arranged in series according to the angular and wave functions of the circular cylinder:

$$\begin{aligned}
&u_s = \sum_n u_{ns} e^{in\varphi_s},\ w_s = \sum_n w_{ns} e^{in\varphi_s};\\
&\Phi_{1s} = \sum_n A_{ns} H_n^{(1)}\left(k_1 r_s\right) e^{in\varphi_s};\quad s = 1\ldots 2.\\
&\Phi_{2s} = \sum_n B_{ns} J_n\left(k_2 r_s\right) e^{in\varphi_s};
\end{aligned} \tag{3}$$

To ensure the fulfillment of conditions (2) of the conjugation of the acoustic fields of the screen and the transducer in the external environment, the transfer of coordinate systems was carried out based on addition theorems [7,8] for cylindrical wave functions. Then, the acoustic fields $\Phi_1\left(r_s,\varphi_s\right)$ take the form:

$$\begin{aligned}
&\Phi_1\left(k_1,r_s,\varphi_s\right) = \sum_n A_{ns} H_n^{(1)}\left(k_1 r_s\right) e^{in\varphi_s} +\\
&+\sum_n A_{nq} \sum_m J_m\left(k_1 r_s\right) H_{n-m}^{(1)}\left(k_1 r_{qs}\right) e^{i(n-m)\varphi_{qs}},\\
&s = 1,2; q \ne s,
\end{aligned} \tag{4}$$

here $r_{qs} = l$, φ_{qs} – distance and phase between elements s and q.

Algebraization of the system of functional equations (1) and (2) using relations (3) and (4) and expression $E_{\varphi_s} = -\frac{\psi_{0s} M_s}{2\pi r_s}$ for the intensity of the electric fields of the screen and the converter during their circular polarization based on the properties of completeness and orthogonality of systems of angular functions on the interval $\left[0;2\pi\right]$ allows you to determine the unknown coefficients of expansions (3) by solving an infinite system of linear algebraic equations of the form:

$$\begin{cases}
-B_m J_n'\left(k_1 r_{1s}\right) + ic_{1s} w_m = 0;\\
icw_{ns} - \left[A_{ns} H_n'^{(1)}\left(k_1 r_s\right) + \sum_m A_{nq} J_m'\left(k_{1s} r_1\right) H_{n-m}^{(1)}\left(k_1 l\right) e^{i(n-m)\varphi_{qs}}\right] = 0;\\
R_{ns} w_{ns} + \frac{\alpha_s}{h_s} i\omega\rho_1 \left[A_{ns} H_n^{(1)}\left(k_1 r_s\right) + \sum_m A_{nq} J_m\left(k_1 r_s\right) H_{n-m}^{(1)}\left(k_1 l\right) e^{i(n-m)\varphi_{qs}}\right] -\\
-\frac{\alpha_s}{h_s} i\omega\rho_{2s} B_{ns} J_n\left(k_2 r_s\right) = -\frac{e_{33s}}{C_{33s}^E}\frac{\psi_{0s} M_s}{2\pi}\int_0^{2\pi} e^{i\upsilon\varphi_s} d\varphi_s;
\end{cases} \tag{5}$$

$$R_{s\upsilon} = \frac{\upsilon^2\left(1+\beta_s \upsilon^2\right)^2 - \left(1+\beta_s \upsilon^4 - \alpha_s\gamma_s\omega^2\right)\left(\upsilon^2 + \beta_s\upsilon^2 - \alpha_s\gamma_s\omega^2\right)}{\upsilon^2\left(1+\beta_s\right) - \alpha_s\gamma_s\omega^2}$$

In system (5) $A_{s\upsilon}$ and $B_{s\upsilon}$ – are the unknown coefficients of decomposition of acoustic fields into series by cylindrical wave functions on the outside and inside, respectively, of the s - th element; the first derivative of the function is marked with a dash; J_υ and $H_\upsilon^{(1)}$ the traditional notation of the Bessel and Hankel functions.

3. RESULTS OF THE NUMERICAL EXPERIMENT AND THEIR DISCUSSION

We will apply the obtained ratios for the quantitative assessment of the dynamic properties of the transducer in the presence of an electroelastic acoustic screen with operational control of its parameters. We will take the frequency dependence of the amplitudes and phases of the oscillating speed (mechanical field) and acoustic pressure (acoustic field) as the characteristics of the transducer studied. We will determine these characteristics on the surface of the transducer at a point on the opposite side of the acoustic screen.

In the calculations, it was assumed: piezoceramics of the composition ZnTiBPb-3 with density $\gamma = 7210\,\frac{\text{kg}}{\text{m}^3}$, piezo constant $e_{33} = d_{33} C_{33}^E$, where is the piezo modulus $d_{33} = 286 \cdot 10^{-12}\,\frac{\text{C}}{\text{N}}$, dielectric constant $\varepsilon_{33}^D = 1280 \cdot 8.85 \cdot 10^{-12}\,\frac{\text{F}}{\text{m}}$ and modulus of elasticity $C_{33}^E = 136 \cdot 10^{10}\,\frac{\text{N}}{\text{m}^2}$; average radii of piezoceramic shells:

to the transducer $r_2 = 0.068\,\text{m}$ at thickness $h_2 = 0.008\,\text{m}$, number of prisms $M_2 = 48$ and screen (first version) $r_1 = 0.068\,\text{m}$ at thickness $h_1 = 0.008\,\text{m}$, number of prisms $M_1 = 48$, and excitation voltages $\psi_2 = 200\,\text{V}$. The screen with piezoceramics of the composition TiBK-3 with density $\gamma = 5400\,\frac{\text{kg}}{\text{m}^3}$, piezo constant $e_{33} = d_{33} C_{33}^E$, where is the piezo modulus $d_{33} = 113 \cdot 10^{-12}\,\frac{\text{C}}{\text{N}}$, dielectric constant $\varepsilon_{33}^D = 1200 \cdot 8.85 \cdot 10^{-12}\,\frac{\text{F}}{\text{m}}$ and modulus of elasticity $C_{33}^E = 105 \cdot 10^{10}\,\frac{\text{N}}{\text{m}^2}$; $r_1 = 0.068\,\text{m}$ at thickness $h_1 = 0.008\,\text{m}$, number of prisms $M_1 = 48$; electric excitation voltages at zero mode of oscillations $\psi_2 = 200\,\text{V}$ and $\psi_1 = \{0;120;200\}\,\text{V}$ with a phase shift between ψ_1 and ψ_2 $\varphi = \left\{0;{}^{\pi}\!/_{2};\pi\right\}$; the distance between the surfaces of the emitter and screen shells was assumed to be equal to $3\,\text{mm}$. The inner cavities of both shells were vacuumed ($\rho_1 c_1 = 0$), and the external environment was water ($\rho c = 1.5 \cdot 10^6\,\frac{\text{kg}}{\text{m}^2\text{s}}$).

Let's take into account several remarks. First, since the dimensions of the transducer and acoustic shield shells are the same, but the shells themselves are made of the same (option 1) or different (option 2) compositions of piezoceramic material, the natural resonant frequencies of the transducer and the screen at the zero mode of their oscillations can be the same or different from each other. This makes it possible to carry out a comparative analysis of the dynamic properties of a typical element of a location device with one-frequency and two-frequency versions of the typical element.

Secondly, in the absence of electrical excitation of the piezoceramic shell of the acoustic screen, it is a cylindrical body with complex acoustic properties in different frequency ranges [12].

The frequency dependences of the dynamic behavior of the mechanical and acoustic fields of the transducer at the point $(r_{22} = 0, \varphi_2 = 0)$ in the presence of an electroelastic screen with an operational change of its electrical load are shown, respectively, in **Fig. 2** and **Fig. 3** for option 1; in **Fig. 4** and **Fig. 5** for option 2.

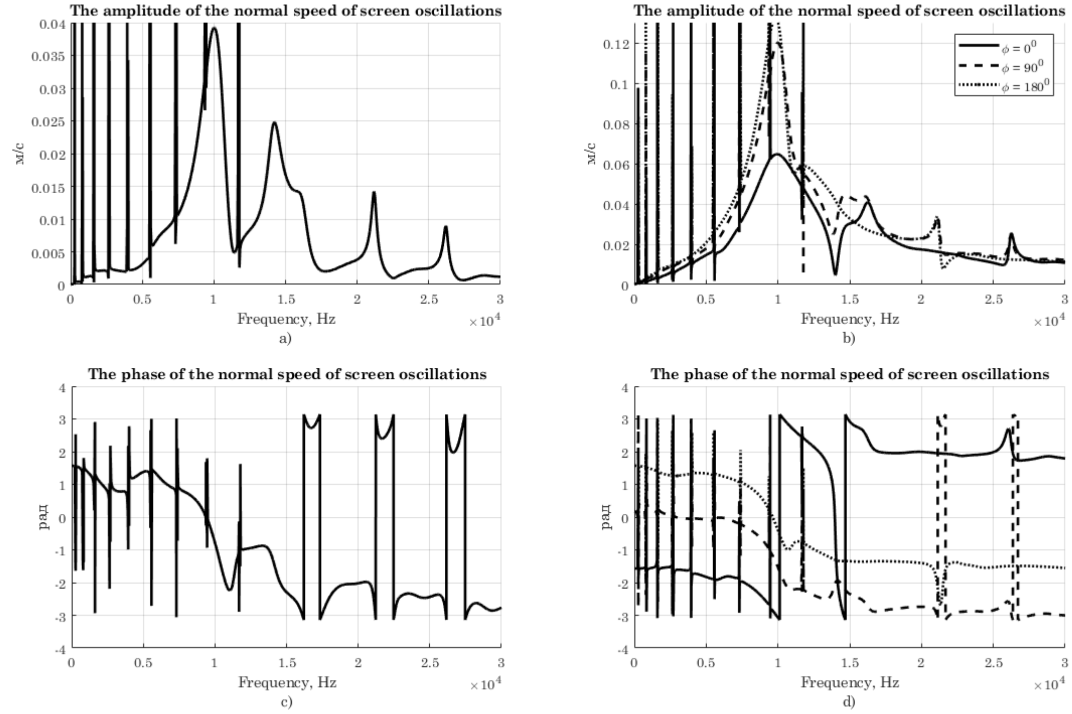

Fig. 2 – Frequency dependences of the amplitude (a, b) and phase (c, d) of the oscillating speed of a point on the surface of the electroelastic screen (ZnTiBPb -3) without its electrical excitation $\Psi_1 = 0\,\text{V}$ (a, c) and when excited by a voltage $\Psi_1 = 200\,\text{V}$ (b, d)

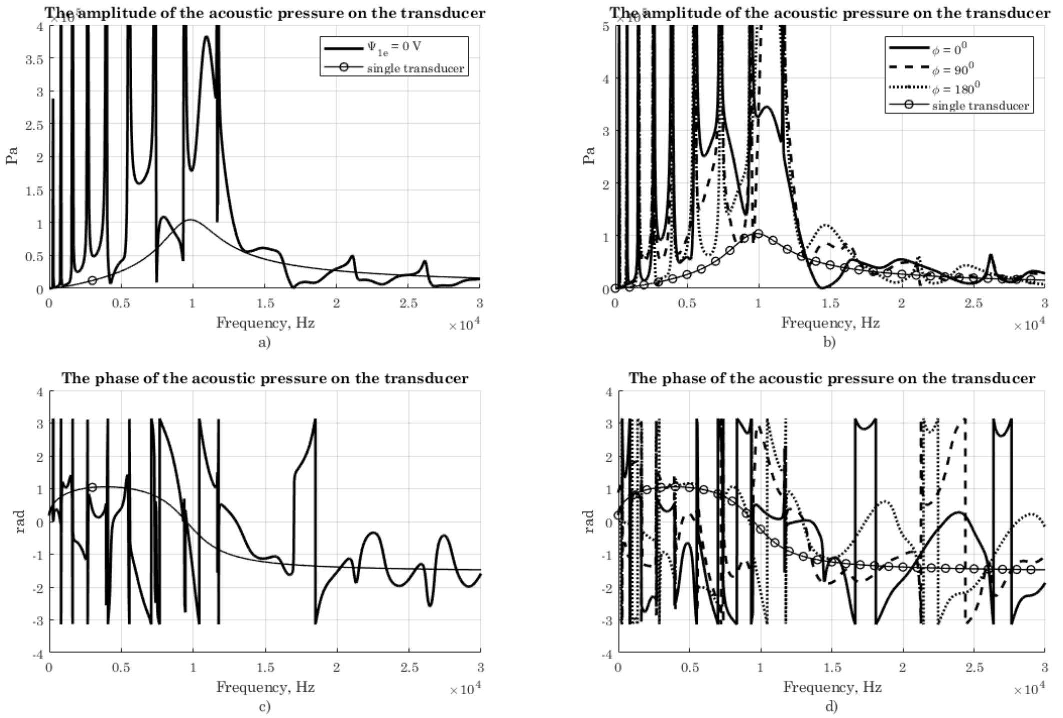

Fig. 3 – Frequency dependences of the amplitude (a, b) and phase (c, d) of the acoustic pressure of a point on the surface of the transducer in the presence of an electroelastic screen (ZnTiBPb -3) without its electrical excitation $\Psi_1 = 0\,\text{V}$ (a, c) and when excited by a voltage $\Psi_1 = 200\,\text{V}$ (b, d)

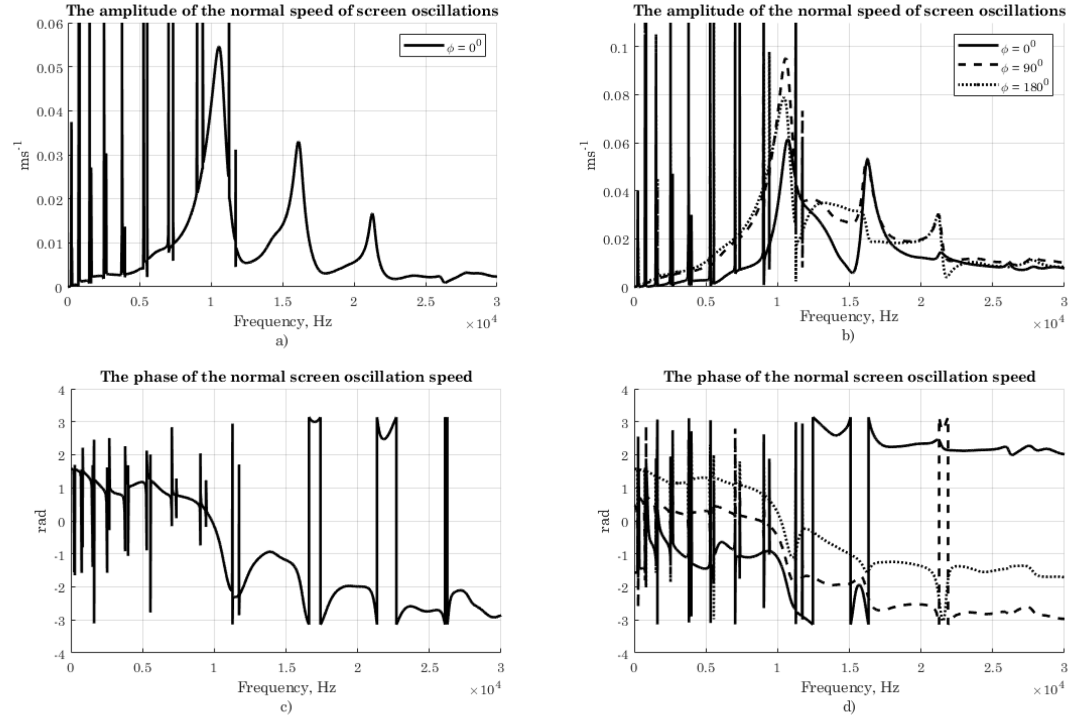

Fig. 4 – Frequency dependences of the amplitude (a, b) and phase (c, d) of the oscillating speed of a point on the surface of the electroelastic screen (TiBaK-3) without its electrical excitation $\Psi_1 = 0\,\text{V}$ (a, c) and when excited by a voltage $\Psi_1 = 200\,\text{V}$ (b, d).

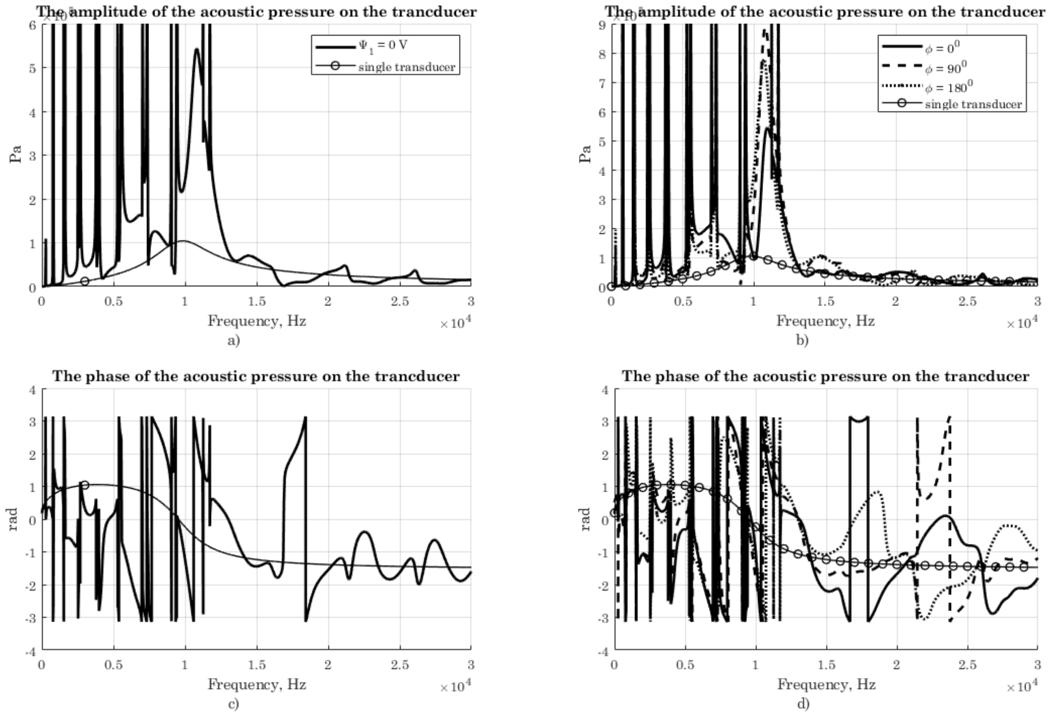

Fig. 5 – Frequency dependences of the amplitude (a, b) and phase (c, d) of the acoustic pressure of a point on the surface of the transducer in the presence of an electroelastic screen (TiBaK-3) without its electrical excitation $\Psi_1 = 0\,\text{V}$ (a, c) and when excited by a voltage $\Psi_1 = 200\,\text{V}$ (b, d)

In the range of frequencies of mechanical resonances, its acoustic properties are close to the properties of a perfectly pliable body, in the range of frequencies far from the frequencies of mechanical resonances of the shell, they are close to the properties of an absolutely rigid body. In the intermediate frequency ranges between the frequencies of mechanical resonances and far from them, the acoustic properties of an electroelastic cylindrical body have impedance acoustic properties. Thus, an acoustic screen in the form of an electroelastic cylindrical body without electrical excitation, depending on the frequency range in which it is used, can have the acoustic properties of acoustically soft, acoustically rigid or impedance screens.

Analysis of the given curves shows that the transducer's mechanical and acoustic dynamic properties in the presence of an electroelastic acoustic screen, regardless of the values of their resonant frequencies, have a resonant character. At the same time, it is possible to distinguish three conditional zones in the presented dependencies – low-frequency, resonant, and high-frequency.

In the low-frequency zone, which covers the frequency range $f < 0.7f_0$, where f_0 – is the natural resonant frequency of the converter, the following physical factors operate. As is known [9, 10], in the mechanical field of the converter, with a decrease in frequency, the intrinsic mechanical impedance of the shells increases rapidly since it has an elastic character in this zone. At the same time, the radiation impedance drops as the wavelength radius of the shells decreases. This leads to a reduction in the role of the interaction of the transducer shells and the screen on the acoustic field when a typical element form it. Therefore, the oscillating speeds (**Fig. 2** та **Fig. 4**) are completely determined by the mechanical impedance of the converter shell. In this regard, they begin to be almost the same, regardless of the excitation conditions of the electroelastic screen (**Fig. 2**b та **Fig. 4**b). At the same time; energy transformation takes place in both shells, which determines the interaction of physical fields in them. The consequence of this interaction is, firstly, a significant increase in the number of mechanical resonances in the low-frequency zone and, secondly, a significant increase in the amplitudes of the oscillating speeds of the shells. At the same time, we pay attention to the fact that the resonance frequency and amplitude of oscillations of the converter shell are almost independent of the nature of the electrical excitation of the screen, which indicates a small effect of the acoustic interaction of the fields in the system when both shells form them.

The change in the resonant frequencies of the transducer and the screen are manifested in the frequency dependences of the mechanical field of the transducer as follows. First, when the resonance frequencies are the same (**Fig. 2**), a certain number of new resonance frequencies appear in the low-frequency zone, the values of which change by a factor $2 \ldots 10$ of f_0. Secondly, in the absence of excitation of the screen, the amplitudes of the oscillating speeds differ significantly, and many of them are smaller in magnitude than the corresponding resonant frequency f_0 of the converter and the screen. Thirdly, when the amplitude and phase of the voltage change during the operative control of the excitation of the screen, both the number and the amplitude of their oscillating speeds increase.

When the resonant frequency of the screen is increased compared to f_0 of the converter, the frequency dependence of its mechanical field in the low-frequency zone also changes significantly. The number of new additional mechanical resonances increases, as well as the amplitudes of their oscillating speeds, both in the absence of operational control of the screen (**Fig. 2**a and **Fig. 4**a), and in its presence (**Fig. 2**b and **Fig. 4**b).

In the resonant zone, which covers the resonant region of the transducer $0,7f_0 \le f \le 1.2f_0$, the mechanical impedances of the transducer and screen shells are proportional to their radiation impedances. Therefore, the interaction of physical fields of different nature during energy conversion, and the interaction of the acoustic fields of the transducer and the screen during their formation, as well as the mutual connection of energy conversion and formation processes and the reaction of the environment begin to play a significant role. At the same time, the dynamic change in the nature of the electrical excitation of the piezo-ceramic acoustic screen causes a change in both the resonant frequencies of the "transducer – screen – environment" system and the frequency dependence of the amplitudes of their oscillating speeds. Multiple transitions of the phase characteristic through zero indicate a change in the nature of the full mechanical impedance of a dynamically controlled system from elastic to inertial and vice versa.

Changes in the mechanical resonances of the screen and the transducer in the resonant zone are caused by the following. If these values are the same, the resonant frequency of the transducer in the presence of the screen does not change and remains equal to the frequency of a single transducer (**Fig. 2**a, **Fig. 2**c). When the resonant frequency of the screen increases (**Fig. 4**a, **Fig. 4**c) the resonant frequency of the converter in the presence of the screen also increases. At the same time, the number of new additional mechanical resonances in this zone remains unchanged.

The operational change of the electric voltage of the excitation of the screen when the resonance frequencies of the converter and the screen are the same causes a change only in the amplitudes of the oscillatory speed of the converter at the resonance frequency f_0 (**Fig. 2**a, **Fig. 2**c), and when the resonance frequency of the screen is increased, the resonance frequency of the converter f_0 together with its amplitude of the oscillatory speed.

In the high-frequency zone, which covers the range $f \ge 1.2f_0$, there is an increase in the inherent mechanical impedances of both shells, which are inertial in this zone, and an increase in the radiation impedance of the transducer and the screen with frequency. The result of this is the practical independence of the mechanical field of the transducer (**Fig. 2**) in the presence of an electroelastic dynamically controlled acoustic screen from dynamic changes in the electrical excitation of the screen.

Naturally, the established dynamic properties of the mechanical field of the transducer in the presence of an operatively controlled electroelastic acoustic screen are also reflected in the acoustic field of the typical element "transducer – electroelastic acoustic screen" (**Fig. 3**). And they are related both to the interaction of physical fields and processes during the transformation and formation of energy by this element, and to the dynamic control of the parameters of its electroelastic screen.

The analysis of the given curves (**Fig. 3**) shows that the acoustic field of the studied typical element has a resonant character regardless of the values of the resonant frequencies of the transducer and the screen.

The interaction of physical fields and processes in the transformation and formation of energy determines the placement and enrichment of the frequency spectrum of the converter in the presence of an electroelastic acoustic screen. At the same time, a number of features appear. First of all, both when the resonant frequencies of the transducer and the screen coincide and when they differ in the low-frequency and resonant zones, the amplitudes of the acoustic pressure are many times greater than the amplitudes of the acoustic pressure of the sound field, which is formed by a single transducer. In the high-frequency zone, this effect disappears, and the pressure amplitudes of the transducer in the presence of an electroelastic screen and without it are close to each other, regardless of the frequencies of the main resonances of the transducer and the screen.

Secondly, most of the new additional resonant emissions of acoustic pressure, regardless of the values of the main resonances of the transducer and the screen, are concentrated in the low-frequency zone. All of them are narrow-band, and their resonant frequencies are many times lower than the resonant frequency of a single transducer.. in the resonant zone, the resonant region of a single transducer undergoes significant changes under the influence of an electroelastic acoustic screen placed nearby, regardless of the frequency of its main resonance.

The consequences of operational control of the acoustic field of the transducer through changes in the electrical excitation of the acoustic screen are changes in the values of resonant frequencies, resonant bands, and amplitudes of resonant emissions of acoustic pressure. This is especially evident in the resonance zone. In addition, shown in **Fig. 3** curves make it possible to determine the increase in the role of the acoustic interaction of fields when performing the function of their formation by a typical element in the low-frequency and, especially, resonance zones on the dynamic properties of the element when its operating frequency is increased. The physical reasons for the appearance of such an effect were established during the study of mechanical fields [13].

CONCLUSIONS

It has been shown that a possible approach to ensuring the multi-functionality of modern location acoustic devices is to replace their passive-type acoustic screens with active ones. The latter allows you to quickly change their acoustic properties while also controlling the dynamic properties of the devices. A typical element of such devices is a piezoceramic transducer placed next to an electroelastic acoustic screen.

A physical and computational model of such an element is proposed. It was established that its dynamic properties are determined not only by the conditions of operational control of the electroelastic screen but also by the interaction of physical fields during the implementation of energy transformation and formation processes, as well as these processes themselves. Analytical relations for determining physical fields of various natures are obtained by the method of connected fields in multi-connected domains, taking into account the given interactions. Based on the analysis of the results of the numerical experiment for the mechanical and acoustic fields of the investigated element of the location device with different frequencies of the main resonance of the transducer and the screen, possible changes in the dynamic properties of the element when the amplitudes and phases of the electrical excitation of the transducer and the screen are changed are established. The frequency ranges and physical causes of the greatest impact of these changes are established.

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Залежність динамічних механічних та акустичних властивостей системи «Перетворювач – електропружний екран» від частоти електричного збудження екрана

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Рішення проблеми багатофункціональності акустичних локаційних пристроїв пов'язане зі створенням можливостей оперативного управління характеристиками їх акустичних систем. Для цього їх акустичні екрани повинні бути виконані в електропружних тілах. Для типового елемента такої системи, що складається з перетворювача та електропружного акустичного екрана, задача визначення аналітичних співвідношень, що описують механічне, акустичне та електричне поля цього елемента, вирішується зв'язаними полями в багатозв'язаних областях. При цьому взаємний зв'язок акустичних полів під час їх формування, взаємовплив процесів перетворення енергії та формування, вплив процесу оперативного управління характеристиками електропружного акустичного екрана та реакції навколишнього середовища на враховано збудження в них акустичних хвиль. У результаті аналізу результатів чисельного експерименту для варіантів конструкції типового елемента з однаковими та різними частотами основних резонансів перетворювача та екрана встановлено залежність механічних та акустико-динамічних властивостей елемента від в ході оперативної зміни встановлено та порівняно характеристики екрана. Визначено закономірності цих властивостей для різних діапазонів частот і надано їх фізичне обґрунтування.

Ключові слова: Елемент "перетворювач-електропружний екран", Оперативне керування, Механічне поле, Динамічні властивості, Активний акустичний екран, Механічні поля.