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Research Article

The Frequency Characteristics of the Receiving Piezoceramic Transducer with Coordinating Layer

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Abstract: The problem of the sound reception by means of cylindrical transducer in the circular layer is considered in "through" formulation. Electroelastic properties of piezoceramic shell and the transition layer was taken into account in the solution of declared problem. Features of formation of the amplitude frequency characteristics of the sensitivity of piezoceramic receiving transducer with a wave layer are considered for different material layer. The interaction of elasticity cylindrical shell layer and associated mass of the environmental, as well as multimode oscillation system are provided the control parameters of the frequency response sensitivity of a cylindrical transducer.
Keywords: shell, multimode converter, the method of partial regions, the wave layer, piezoceramic receiving transducer, electricalelastic properties, sensitivity.

INTRODUCTION

Modern underwater electroacoustic transducers reached intricate designs due to consolidation of technological methods, providing electrical insulation, sealing, and the necessary of structural strength.

Formation of related acoustic, mechanical and electrical fields of the piezoceramic transducers requires a detailed study taking into account of the structural features of layered matching funds, screening, and technological elements. Changing the geometrical characteristics, inertia and elastic properties matching and shielding layers leads to a change in the wave size of the transmitter-receiver of oscillatory system and, accordingly, the conditions of formation of a complete acoustic field. It is related to a change in the oscillation mode of the piezoelectric element, and as a result - a modification of the nature and spatial orientation of the stray field. The procedure for the formation of complete and scattered fields of different types of objects without considering the interactions of acoustic, mechanical and electrical fields are well represented in the traditional acoustic periodicals. It is noted in [1 – 3], and the basic provisions solution of the proposed electroelastic through type problem, taking into account the features of the interaction of these physical fields are described in [4, 5].

The present work is devoted to determining the frequency response characteristics of the receiving cylindrical transducer represented by a thin-walled electroelastic (piezoceramic) shell with a continuous open-electrode, which is connected to an active electrical load. The transmitter operates in a closed ring layer, which represents the matching device and provides at the same time, hydro- and electrical isolation of the oscillating system.

Therefore, this article is a continuation of the work [6], in which a mathematical model taking into account the effects of elastic interaction of a cylindrical shell, located in a circular wave layer to the environment with the use of the classical theory of piezoelectricity, corresponding to her simplified Maxwell's equations, the equations for the acoustic field (Helmholtz equation), as well as the power and kinematic coupling surface conditions "cylindrical shell - work environment." Wherein fixing conditions of the converter idealized and considered as not affecting on the resultant sensitivity.

Thus, the aim of the work is a numerical study of the mathematical model developed in the calculation of the frequency response characteristics of a cylindrical electroelastic converter for different values of the impedance of the electric load.

MAIN PART

In perfect little compressible fluids with density ρ and speed of sound c posted oscillating system, consisting of a single cylindrical piezoceramic transducer infinite length (Fig. 1), which is located in a closed wave ring layer. The converter seems electroelastic circular, radially polarized shell of arbitrary radius R_{0s} with wall thickness $h_{0s} = R_{1s} - R_{0s}$. Inside the converter – a vacuum.

The nature of the mechanical vibrations of the oscillating system voltage converter satisfies Newton's equation and the strain tensor components and the displacement vector bound Cauchy equations [4-7].

For define the boundary conditions of the task to the electric field at loading the electrode on the external electrical resistance $Z_н$:

$$\frac{\partial}{\partial t}\int_S (\mathbf{n}\cdot\mathbf{D})\, dS = -\frac{U_н}{Z_н}$$

Where $U_н$ – potential difference across the load $Z_н$ of the electrode; **D** – Electric induction vector; S – area surface of electrodeposited (in this specific situation $2\gamma = 2\pi$).

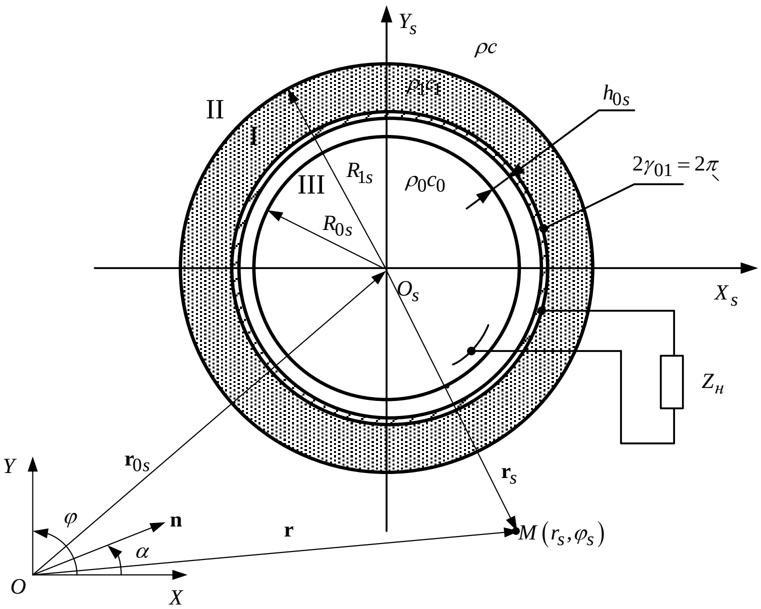

Fig-1: Piezoceramic converter and the coordinate system

Electric induction vector components **D** determined based on the geometry of the electrode. In this case on the inner and outer surface of the converter for radial and angular component vector electric induction **D** performed condition:

$D_\varphi = D_z = 0$,

where D_φ, D_z – district and meridional components of the electric induction vector. That is, the electric induction vector is determined only by the radial component.

For mode idling use the expression:

$$\frac{\partial}{\partial t}\int_S (\mathbf{n}\cdot\mathbf{D})\, dS = 0.$$

This condition defines a situation, where $I_н = 0$.

With the closure of the electrode alignment of charges to them is accompanied by the instantaneous decrease in potential difference. Consequently, the electric field tension E_r (E_r – radial component of the electric field) will decrease immediately to the value $E_r = 0$.

The electrical state of the piezoelectric deformable membrane satisfies the simplified Maxwell equations [7]. The component of the electric field in the piezoelectric ceramics is determined by the condition [4]:

$$U_н = -\int_{-\frac{h_{0s}}{2}}^{\frac{h_{0s}}{2}} E_{rs}\big|_{2\gamma_{01}}\, dh$$

The surface density of electric charge is determined by the component of the vector of electric induction, which is oriented along the normal to the surface of the piezoelectric membrane electrodeposited [5]:

$$Q = \int\limits_S \mathbf{D} dS \Rightarrow A \int\limits_{-\gamma_{0s}}^{\gamma_{0s}} D_r \, d\varphi_s$$

where $dS = Ad\varphi_s$

For shells with radial polarization in accordance with the [4] electric induction is expressed through the equation of state as follows:

$$D_r = \varepsilon_{33}^s E_r + e_{31}\left(\varepsilon_\varphi + \varepsilon_z\right)$$

where the meridional component of the strain tensor ε_z is equal to zero (as a result of infinity shell $\varepsilon_z = \partial V_z / \partial z = 0$).

For the case of full electrodeposited taking into account the properties of completeness and orthogonality of the electric field

$$E_{rs} = E_{rs} \,|_{2\gamma_{01}} = -\frac{U_н}{h_0} \cdot 2\pi$$

Note, that the true situation $\partial E_{rs} / \partial \varphi_s = 0$ since changes E_{rs} on the angle for this type electrodepositing missing.

We define $U_н$ like the voltage drop in the load circuit electrode

$$I_н = -\frac{U_н}{Z_н} = \int\limits_S \frac{\partial D_r}{\partial t} dS = \int\limits_0^{2\pi} (i\omega) D_r d\varphi_s,$$

Thus, the electric field is determined by the frequency dependence of the change in strain, which is almost entirely determined by the frequency-dependent variation of the radial component of the electric displacement vector:

$$E_{rs} = -\frac{i\omega Z_н A \dfrac{e_{31}}{R_{0s}} 2\pi}{i\omega\varepsilon_{33} A Z_н 2\pi - h_{0s}} W_m$$

The following system of equations determines the unknown coefficients of expansions of fields that allow finding the basic characteristics of acoustic, mechanical and electrical fields.

$$\begin{cases} B_m = \dfrac{\varsigma_{R_{1s}}^m(\omega) - \Delta 1_{R_{0s}}^m(\omega)\beta_{R_{1s}}^m(\omega)}{\xi_{R_{1s}}^m(\omega) - \beta_{R_{1s}}^m(\omega)\Delta_{R_{0s}}^m(\omega)}; \\ A_m = -B_m \Delta_{R_{0s}}^m(\omega); \\ E_m = \dfrac{\frac{k_1}{k}\left[A_m I_m'(k_1 R_{1s}) + B_m N_m'(k_1 R_{1s})\right] - i^m e^{-im\alpha} I_m'(kR_{1s})}{H_m'(kR_{1s})}; \\ V_m^{(s)} = -iW_m \dfrac{M_m}{F_m(\omega)}; \\ W_m = -i\dfrac{k_1}{\omega}\left(A_m I_m'(k_1 R_{0s}) + B_m N_m'(k_1 R_{0s})\right). \end{cases}$$

THE RESULTS OF NUMERICAL RESEARCH

Presentation of the receiving transducer in a sensor-generator of electricity involves determining the amplitude and frequency characteristics of the electric fields in the form of sensitivity as the output terminals of the voltage converter module piezoceramic shell, referred to the pressure in the surrounding acoustic field:

$$\gamma = \left| U_н / p_0 \right|$$

where p_0 – acoustic impact on the piezoceramic shell. Acoustic impact on the piezoceramic shell consists of the incident plane wave field, which generates the reflected sound waves as well as the acoustic field inside the layer. $U_н$ – electric voltage on the external load - resistance $Z_н$.

Said resistance $Z_н$ in general, is a complex ($Z_н = R_н + iX_н$ where $R_н$ и $X_н$ – active and reactive components of the total resistance $Z_н$). In this case the unknown is the potential difference $\Delta\Psi = U_н$ and the conduction current I_{np} in the external circuit. Note that the conduction current corresponds to the directional movement of free charges in an external circuit conductor. Thus, the conduction current to the load circuit of the electrode is determined by Ohm's Law equation:

$$I_{np} = U_н / Z_н$$

As is known (for example, [4, 6, 7]), the bias current I_D is proportional to the rate of change of electrical induction $\mathbf{D}$ $\left(D_r, D_\varphi, D_z\right)$. It occurs when the electric field intensity and the displacement characteristic of charges related to the structure of the material (in this case – the piezo). Thus, the bias current is determined by the polarization of the material, and relevant traffic-related charges.

Consider the results of the calculation of amplitude-frequency dependency of sensitivity γ. Fig. 2 – 7 shows a family of curves that show the frequency dependence of the sensitivity of the module to the oscillating system, the inverter which is enclosed in a half-wave layer. In this situation, to investigate the relative impedances of different layers by using various materials such as PPU-10, rubber and steel.

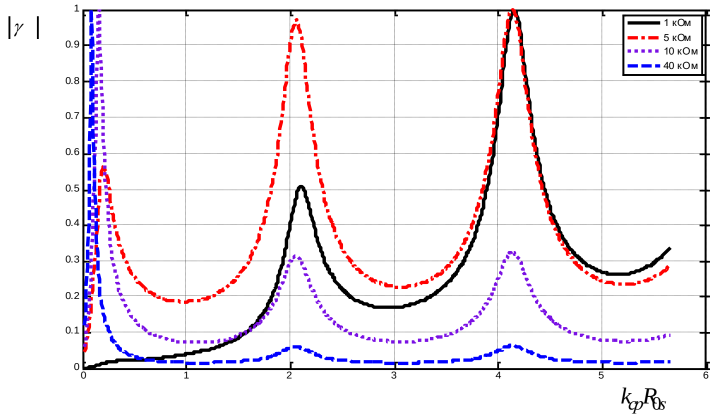

Fig-2: The sensitivity of the oscillating system with a half-wave layer (material PUR-10)

Thus, the deformable cylindrical shell under the influence of an external acoustic field is characterized by a specific stress-strain state of compression, stretching along the polar coordinates of the corner.

Thus, for half-wave short-circuit layer ($Z_н = 1$ Om) resonant frequency response is characterized by three peaks that are different from each other in the region of small wave receiver sizes $k_{cp}R_{0s}$.

As seen from the frequency response of the sensitivity of the results ARC to a half-wave layer (Fig. 2) oscillating system is multiresonance at what resonance regions can occur with coincidence of the current frequency with the resonance frequencies of the shell. Thus, for a given thickness to the calculated wave frequency band received three frequency regions:

- The first range of values $k_{cp}R_{0s} = 0.2$, the amplitude of which increases with increasing values of the electrical load;
- A second range of values $k_{cp}R_{0s} = 2.1$ coincides with the resonance frequency of the piezoceramic zero shell mold oscillation predetermined size and selected material;
- The third range of values $k_{cp}R_{0s} = 4.2$, due to the presence of the wave matching layer.

The change in the value of the active component of the electric resistance leads to an increase or decrease in the amplitude of electrical sensitivity in the respective areas. So, for the first field amplitude sensitivity at least 1 kOm., and the maximum at 40 kOm.

Thus, there is increasing the total decrease in sensitivity with simultaneous smoothing of the frequency response throughout the frequency range investigated. Thus the greatest differences are observed at low values. The decrease is due to the sensitivity of the elastic interaction forces that are commensurate with the strength of the Coulomb interaction, which means the load impedance mismatch. The lower the load impedance, the more elastic effects play a role in terms of influence on the bias current.

ARC sensitivity (Fig. 2) for a half-wave layer made of polyurethane foam, is the radius of the wave converter periodic function.

The situation is similar for the layer which is made of steel (Fig. 3). The difference is only the values of the resonance regions, peaks are defined as $k_{cp}R_{0s} = 0.1$, $k_{cp}R_{0s} = 1.5$, $k_{cp}R_{0s} = 3.6$ due to the change of wave resistance and reflective properties that are determined by the degree of stiffness (of elasticity) of the material of the wave layer.

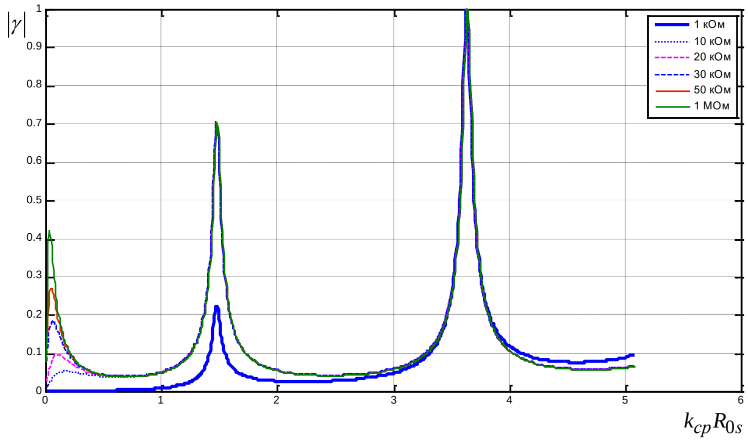

Fig-3: The sensitivity of the oscillating system with a half-wave layer (material - steel)

It is obvious that by manipulating the technological materials of the layer selection can be controlled the resonances location of the frequency response characteristics.

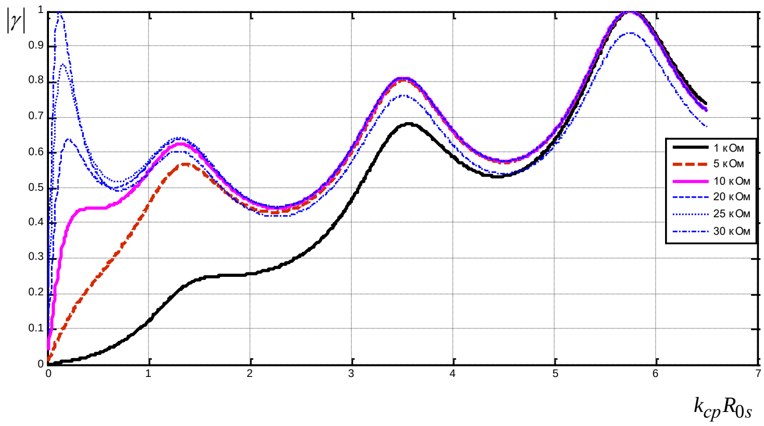

Fig-4:The sensitivity of the oscillating system with a half-wave layer (material - rubber)

Changing the layer material, and therefore, the wave parameters of the oscillating system will assess the situation on the example of cellular rubber 51-1415 (Fig. 4).

It can be seen from the presented results when using a half-wave layer frequency response curve defines oscillating system as an broadband.

Thus in this frequency band by increasing the value of active component electric resistance are smoothed the frequency response sensitivity in the low range.

However, a distinctive feature of each of the diagrams is the presence of low-frequency peak of the amplitude-frequency characteristics, which is modified by increasing the electrical load.

CONCLUSIONS

The study of the frequency characteristics of the electric fields of the receiving cylindrical transducer which disposed in the annular layer taking into account the electrostatic properties of the piezoceramic shell and transition layer using "through" method are established that the interaction of elasticity cylindrical shell layer and associated mass of the environmental, as well as multimode oscillation system are provided the control parameters of the frequency response sensitivity of a cylindrical transducer.

The changing in the inertial and elastic characteristics matching layer in consideration of multimode system determines at fixed aperture electrode:

- Fixed modal composition of the resulting electrical signal to the load;
- Sound transmission layer for different modes vibrations of the shell;

- Changing of the amplitude of the voltage on the electrode load over the frequency range and the respective upper and lower modes.

REFERENCES

1. Grinchenko VT, Vovk IV, Matsipura VT. Acoustics wave problems: monography. Kiev: Interservis, 2013.
2. Sridhara BS, Crocer MJ. Review of theoretical and experimental aspects of acoustical modeling pf engine exhaust system. J. Acoust. Soc. Amer. 1994;95(1): 2363-2370
3. Hwang WS. A boundary integral methodы for acoustic and scattering. J. Acoust. Soc. Amer.1997;101 (6): 3330-3335
4. Petrishchev O. N Harmonic oscillations of piezoceramic elements Part 1: The harmonic vibrations of the piezoelectric elements in a vacuum and the method of resonance-antiresonance. Kiev: Avers, 2012.
5. Filipova NY, Korzhik AV. Formation of the scattered field receiving electroelasticity cylindrical transducer in a closed ring layer. Information processing systems. 2013; 7 (114): 35 - 39.
6. Filipova NY, Korzhik AV. Statement and solution of the problem of the reception of sound electroelasticity cylindrical transducer with fully electrode surface placed in a closed wave layer. Electronics and Communications, 2012;1 :18 - 24.
7. Grinchenko VT, Ulitko AF, Shulga N. A Mechanics of bound fields in structural elements. Electroelasticity. Vol .5. Kiev: Nauk. Dumka, 1989.
8. Janger MG, Rosato FJ. The propagation of elastic Waves in Thin- Walled Cylindrical Shells. J. Acoust. Soc. Amer.1954; 26 (5):709-713.
9. Mason WP,Thurston RN,Physical acoustics: principles and methods (volume 17), New York, Academic Press, 1984
10. Eschenauer H, Olhoff N, Schnell W. Applied structural mechanics: fundamentals of elasticity, load-bearing structures, structural optimization, Springer-Verlag Berlin Heidelberg, 1997.