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ON A POSSIBILITY OF ACOUSTIC MATCHING FOR HYDROACOUSTIC TRANSDUCERS OF SMALL WAVE SIZE

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The problem of one-frequency matching of complex impedances with the help of an acoustic lumped-parameter matching system is considered. The solution is illustrated by calculations of matching systems for hydroacoustic transducers of small wave size. The properties of matching systems and the possibilities of their optimization are discussed.

In designing small-size (compared with the working frequency wavelength) underwater electroacoustic transducers, there arises the problem of their matching with the medium [1] on account of two circumstances: (*i*) the radiation impedance Z_S of such transducers has a small real component: $R_S \ll X_S$, $R_S \ll S\rho c$, where $R_S = \operatorname{Re} Z_S$, $X_S = \operatorname{Im} Z_S$, S is the radiating surface area, and ρc is the wave resistance of the medium; (*ii*) the dimensions of conventional matching systems in the form of one or several layers are usually on the order of the wavelength, which in the given case is unacceptable.

One of the possibilities of solving this problem involves the use of discrete lumped-parameter systems. In such structures, usually, there is no one-to-one relation between the resonance frequencies and dimensions. Therefore, matching systems based on them can be made sufficiently compact.

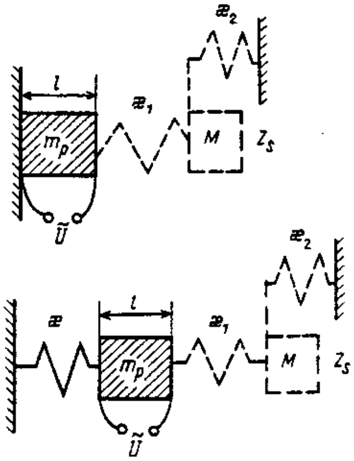

Fig. 1

Piezoelectric transducers with a matching system (shown by the dashed lines).

In this paper we consider one-frequency matching of small-size piezoelectric transducers of two types: one of them is a piezoelectric element of small wave dimensions secured with its idle end to a rigid wall; the other is an oscillatory system in which the inertial element is piezoelectrically active and the resilient element is passive [1]. We shall consider a section of a mechanical bandpass filter as a matching system. The general view of transducers with a matching system is illustrated diagrammatically in Fig. 1.

The problem of matching will be solved if the condition

$$Z_S^* = \frac{b_{11}Z + b_{12}}{b_{21}Z + b_{22}} \tag{1}$$

is fulfilled, where Z is the input mechanical impedance of the transducer, the asterisk denotes complex conjugation, b_{jk} are the elements of the characteristic matrix $||B||$ of the matching unit having the form

$$||B|| = \begin{pmatrix} \dfrac{-\omega^2 M + \varkappa_1 + \varkappa_2}{\varkappa_1} & \dfrac{\omega^2 M - \varkappa_2}{i\omega} \\ -\dfrac{i\omega}{\varkappa_1} & 1 \end{pmatrix}$$

(ω is the cycle frequency, i is the imaginary unity, the meaning of the parameters M, $\varkappa_1$, $\varkappa_2$ is clear from Fig. 1).

Separating the real and imaginary parts in (1), we obtain a nonlinear system of two equations for determining the parameters of the matching unit. The solution of the system has the form

(a) at $R = R_S$ ($R = \operatorname{Re} Z$):

$$M = -\frac{X_S}{\omega} + \frac{X}{\omega} + \frac{\varkappa_2}{\omega^2}, \quad \varkappa_1 = \frac{\omega(R^2 + X^2)}{2X_S},$$

where $X = \operatorname{Im} Z$;

(b) at $R \neq R_S$ (the case of practical interest):

$$M = \sqrt{\frac{R_S}{\omega^2}\frac{R^2 + X^2 - RR_S}{R}} - \frac{X_S}{\omega} + \frac{\varkappa_2}{\omega^2},$$

$$\varkappa_1 = \frac{R\omega\sqrt{R_S(R^2 + X^2 - RR_S)/R} - X\omega R_S}{R - R_S}.$$

The conditions of physical feasibility of the matching system ($M > 0$, $\varkappa_1 > 0$, $\operatorname{Im} M = 0$, $\operatorname{Im} \varkappa_1 = 0$) impose definite limitations on the permissible values of Z and Z_S (being cumbersome, they are omitted here; it follows from them, in particular, that it is useful to put $\varkappa \ll \varkappa_1$). In what follows we shall use, for simplicity, the "effective" mass of the matching unit $M_e = M + X_S/\omega - \varkappa_2/\omega^2$, assuming, without loss of generality, that $X_S = 0$ and $\varkappa_2 = 0$.

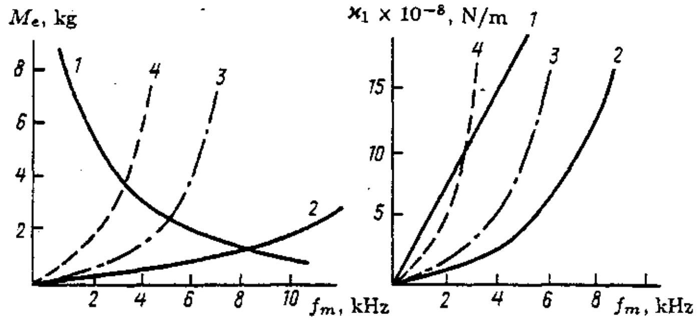

Fig. 2

Dependence of the matching system parameters on the matching frequency f_m for transducers of the first type with $l = 7.2$ cm and $S = 18$ cm^2 (1) and for transducers of the second type with $l = 7.2$ cm and $S = 18$ cm^2 (2), $l = 14.4$ cm and $S = 70$ cm^2 (3), $l = 24$ cm and $S = 70$ cm^2 (4).

The results of calculating the parameters of matching systems for the above-stated types of transducers are given in Figs. 2 and 3. In all the cases the parameters of the piezoelectric material were those of the TsTS-19 piezoceramics [2] and the internal resistance of the power source was chosen to be 600 ohms. It was also assumed that an inductance compensating for the capacity of the piezoelectric element at the matching frequency was connected in series with the internal resistance. The results presented in Fig. 2 suggest that

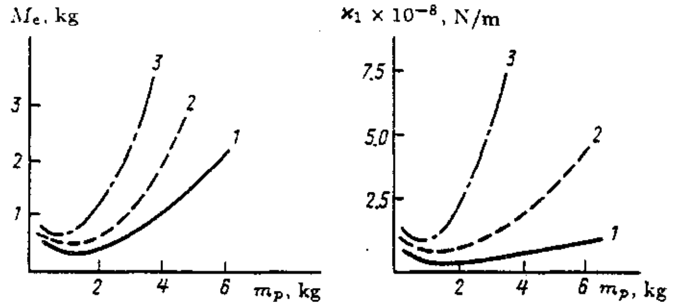

Fig. 3

Dependence of the matching system parameters on the mass of the piezoelectric element for transducers of the second type with $S = 18$ cm^2 at matching frequencies of 1000 Hz (1), 2000 Hz (2), and 3000 Hz (3); the piezoelectric element mass was changed by varying its length.

for the transducer of the first type the mass of the matching system increases as the matching frequency lowers, which is unacceptable for low-frequency matching purposes. The transducer of the second type has properties more favorable for low-frequency matching: the mass and resilience of the matching systems for it decrease with lowering matching frequency.

It is very important that for the second-type transducer at a given matching frequency there are optimum values of the piezoelectric element mass at which the matching system has the minimum mass and resilience (Fig. 3) which are quite acceptable from the practical point of view.

Comparison of the frequency characteristics of the sensitivity of matched and nonmatched transducers in the radiation mode shows an appreciable (more than twofold) advantage of matched transducers both in the sensitivity at the resonance frequency and in the band width.

REFERENCES

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