УДК 681.586

V. M. Sharapov[1], *D.Sc.(Engineering), professor,*
O. N. Petrishchev[2], *D.Sc.(Engineering), professor,*
Zh. V. Sotula[1], *Ph.D.,*
K. V. Bazilo[1], *Ph.D.*
[1]Cherkasy State Technological University
Shevchenko blvd, 460, Cherkasy, 18006, Ukraine
v_sharapov@rambler.ru
[2]National Technical University of Ukraine «Kyiv Polytechnic Institute»
Peremogy ave., 37, Kyiv, 03056, Ukraine

THE INCREASE OF THE SOUND PRESSURE CREATED BY MONOMORPHIC DISK PIEZOELEMENTS

The work is devoted to the improvement of piezoelectric transducers. A special place is occupied by piezoelectric transducers in electric and underwater acoustics, where they are intended for radiation and reception of acoustic vibrations in air or aquatic environment. The overall objective in improving of piezoelectric transducers is to increase their range of action. For transducers manufacture monomorphic and bimorph elements are used. The method of generation of bending vibrations in monomorphic disk piezoelectric elements is described. To enhance bending vibrations in piezoelectric element it is offered to create two oscillating circuits, one of which is created so that electric field vector of stimulating voltage makes an angle with polarization vector and electric field vector of the second circuit is parallel to polarization vector of piezoelectric element. This allows to increase the level of the sound pressure.

Keywords: *piezoelectric transducer, projector, bending vibrations, oscillatory circuit.*

Introduction. Piezoelectric transducers are widely used in electroacoustics, hydroacoustics, measuring technology, nondestructive control, piezomotors, scanners of nanomicroscopes, other fields of science and technics [1–4].

A special place is occupied by piezoelectric transducers in electroacoustics and hydroacoustics, where they are intended for radiation and reception of acoustic vibrations in air or aquatic environment [3: 4].

Piezoelectric transducers used in hydroacoustics are divided into two major classes:

- transducers-receivers of acoustic signal (sensors);
- transducers-projectors of acoustic signal.

A common task in improving the projectors is to increase the range of action that can be achieved by:

- reducing of operating (resonant) frequency and (or)
- increasing of radiation power (increasing of the sound pressure level).

It is known that low-frequency sound travels in water practically without attenuation at distances up to several thousand kilometers by forming in the top layer of the ocean an underwater sound channel –acoustic waveguide of refractive type. Due to this low-frequency acoustics has obvious advantages in a wide range of problems [7; 8].

For making of electroacoustic transducers monomorphic piezoelements, i.e. composed of a single piezoelectric element, and bimorph elements composed of two piezoelectric elements or piezoelectric element and a metal plate connected by gluing or soldering are used [2; 4].

Most frequently in electroacoustics and hydroacoustics asymmetric bimorph piezoelements (BPE), which have a relatively low resonant frequency and create high sound pressure level, are used, but they are more complex than monomorphic and also include an adhesive compound that reduces mechanical strength of BPE [1–4].

Monomorphic piezoelements (MPE) have a relatively high resonant frequency, which in some cases (particularly in hydroacoustics) is a disadvantage. For example, for piezoelectric element Ø66×3 mm of piezoceramics PZT-19 the fundamental resonant frequency of radial oscillations is ~34 kHz. To reduce operating (resonant) frequency in MPE it is necessary to create bending vibrations.

Thus, **the purpose** of this work is to increase the sound pressure level created by bending vibrations of monomorphic disk piezoelectric element.

Traditionally it is believed that in loosely arranged monomorphic piezoelements in the form of plates, bars, disks bending (low-frequency) vibrations do not arise [8]. Meanwhile, the authors observed the effect of such fluctuations appearance in monomorphic piezoelements, but the sound pressure level generated by these piezoelectric elements is very small [5; 6].

To increase bending (low-frequency) oscillations in [5; 6] it is proposed in MPE to create an electric field so that the vector **E** of this field is at an angle α to the polarization vector **P**, and α → 90°.

For the experiments a disk piezoelectric element Ø50×1,2 mm of piezoceramics ЦТБС-3 was used, which is the most often used in electroacoustics. For this purpose, the electrodes on piezoelectric elements were divided into rings (*1*, *1'*) and disks (*2*, *2'*), as shown in fig. 1.

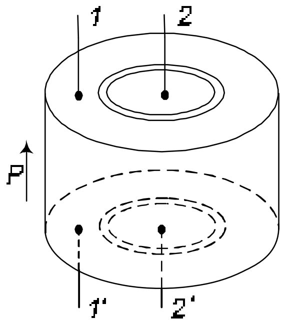
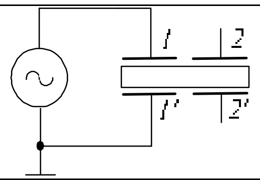
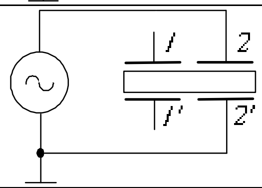
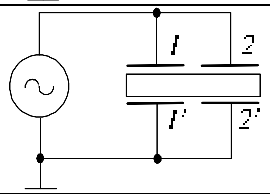
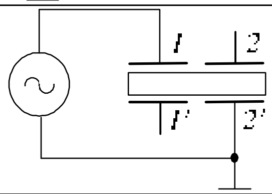
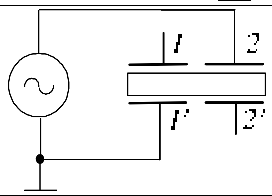


Fig. 1. Disk piezoelectric element

The purpose of these experiments was to determine the sound pressure according to the connection to the generator. Simultaneously the capacitance between relevant electrodes C_{ij} and the resistance r_0 at resonant frequency of bending vibrations 3.07 kHz (internal friction) was measured.

The measurement results are shown in table 1.

Table 1

№	Scheme	*C*, nF	r_0, kOhm	*P*, dB
1		$C_{1-1'} = 22,5$	$r_0 = 2,444$	70
2		$C_{2-2'} = 7,1$	$r_0 = 7,311$	77
3		$C_{\Sigma} = 30,6$	$r_0 = 1,811$	72
4		$C_{1-2'} = 0,76$	$r_0 = 27,5$	79,5
5		$C_{2-1'} = 0,74$	$r_0 = 24,444$	79,5

From table 1 follows:

1. When the generator is connected to disk electrode the created sound pressure level is higher than when it is connected to ring electrode.

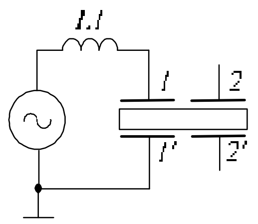
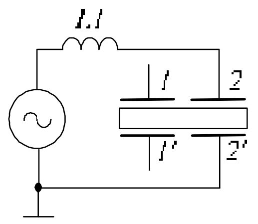
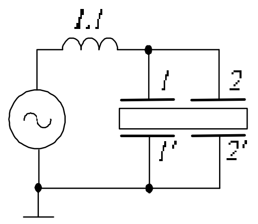
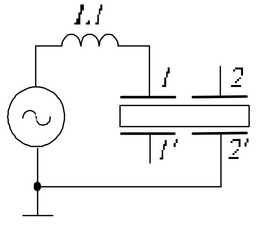
2. In parallel connection of disk and ring electrodes the sound pressure level is practically not growing, although the total capacitance between electrodes C_Σ increased and the resistance r_0 decreased.

3. When the generator is connected to the electrodes of piezoelectric element so that the angle α between electric field and polarization vector approached 90°, the sound pressure increased, despite the fact that the capacity decreased and r_0 increased.

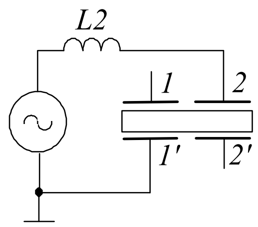
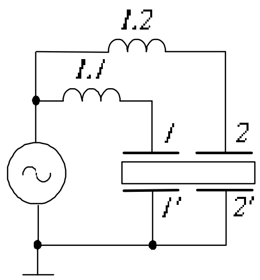
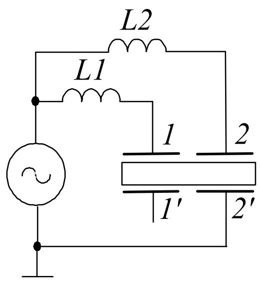
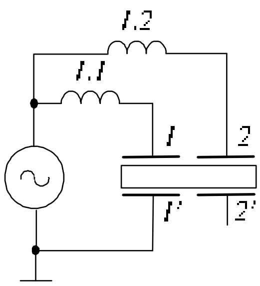
To the sound pressure further increase at the input of piezoelectric element created an oscillating circuit of additional inductance L_{ad} and interelectrode capacitance of piezoelectric element C_{el} (schemes 1–5, table 2).

In the schemes 6–8 (table 2) the excitation of piezoelectric element is made via two channels using two inductances. In the scheme 6 the traditional connection of the parts of piezoelectric element (α = 0°) is used. In the schemes 7 and 8 at the same time the traditional connection is used (α = 0°) (electrodes *2–2'*, scheme 7, electrodes *1–1'*, Scheme 8), and when α ≈ 90° (electrodes *1–2'* scheme 7; electrodes *2–1'*, scheme 8).

Table 2

№	Scheme	C, nF	L, H	r_0, kOhm	P, dB
1		$C_{1-1'} = 22{,}5$	$L_1 = 0{,}109$	$r_0 = 0{,}115$	93
2		$C_{2-2'} = 7{,}1$	$L_1 = 0{,}36$	$r_0 = 0{,}316$	103
3		$C_\Sigma = 30{,}6$	$L_1 = 0{,}082$	$r_0 = 0{,}088$	95
4		$C_{1-2'} = 0{,}76$	$L = 3{,}34$	$r_0 = 2{,}75$	108

Continuation of the table 2

№	Scheme	*C*, nF	*L*, H	r_0, kOhm	*P*, dB
5		$C_{2-1'}$ = 0,74	*L* = 3,41	r_0 = 2,839	108
6		$C_{1-1'}$ = 22,5 $C_{2-2'}$ = 7,1	L_2 = 0,352 L_1 = 0,111	r_0 = 0,2	109
7		$C_{2-2'}$ = 7,1 $C_{1-2'}$ = 0,76	L_1 = 3,50 L_2 = 0,56	r_0 = 0,463	111
8		$C_{1-1'}$ = 22,5 $C_{2-1'}$ = 0,74	L_1 = 0,141 L_2 = 3,41	r_0 = 0,244	114

From the table 2 follows:

1. In this case, as for the case without additional inductance, the sound pressure is higher when the generator is connected to the disk electrode (schemes 1–3).

2. For schemes with an angle $\alpha \approx 90°$ (Schemes 4, 5) the sound pressure is on 5–15 dB higher than that for schemes with the traditional connection.

3. The transducer according to the traditional scheme with one inductance (scheme 3) creates the sound pressure smaller than the transducer with two inductances (scheme 6).

Conclusions:

1. The method of bending vibrations generation in monomorphic disk piezoelectric elements is described.

2. To enhance bending vibrations in piezoelectric element it is proposed to create two oscillating circuits, one of which is created so that electric field vector $\mathbf{E_2}$ of stimulating voltage makes an angle α with polarization vector **P** and electric field vector $\mathbf{E_1}$ of the second circuit is parallel to polarization vector **P** of piezoelectric element.

3. Creating of two stimulating circuits in the circuit of piezoelectric element allows to increase the sound pressure level compared with piezoelectric element with one stimulating circuit.

References

1. Sharapov, V. (2011) Piezoceramic sensors. Heidelberg, Dordrecht, London, New York: Springer Verlag, 498 p.
2. Sharapov, V. M., Musienko, M. P. and Sharapova, E. V. (2006) Piezoelectric sensors. Moscow : Technosphera, 632 p. [in Russian].
3. Sharapov, V., Sotula, Zh. and Kunitskaya, L. (2013) Piezoelectric electroacoustic transducers. Heidelberg, Dordrecht, London, New York: Springer Verlag, 240 p.
4. Sharapov, V. M., Minaev, I. G., Sotula, Zh. V. and Kunitskaya, L. G. (2013) Electroacoustic transducers. Moscow : Technosphera, 280 p. [in Russian].
5. Sharapov, V. M., Petrishchev, O. N., Prohorenkov, A. M., Bazilo, K. V. and Sotula, Zh. V. (2014) Methods of increasing the acoustic monomorphic piezoelements sound pressure. *Izvestiya vuzov. Priborostroenie*, (5). St. Petersburg, pp. 47–50 [in Russian].
6. Sharapov, V. M., Bazilo, K.,V. and Sotula, Zh. V. (2011) Increasing the sound pressure level of transducers low-frequency oscillations based on disk of monomorphic piezoelements. *Visnyk Cherkaskogo Derzhavnogo Technologichnogo Universytetu,* (4), pp. 71–73 [in Russian].
7. Institute of Applied Physics of the Russian Academy of Sciences [Internet]. Available from: <www.ipfran.ru>
8. Underwater electroacoustic transducers: (1983) In: V. V. Bogorodskij (Ed.). Leningrad: Sudostroenie, 248 p. [in Russian].

Стаття надійшла до редакції 18.08.2014.

В. М. Шарапов[1], *д.т.н., профессор*,
О. Н. Петрищев[2], *д.т.н., профессор*,
Ж. В. Сотула[1], *к.т.н.*,
К. В. Базило[1], *к.т.н.*
[1]Черкасский государственный технологический университет
б-р Шевченко, 460, г. Черкассы, 18006, Украина
v_sharapov@rambler.ru
[2]Национальный технический университет Украины
«Киевский политехнический институт»
проспект Победы, 37, г. Киев, 03056, Украина

ПОВЫШЕНИЕ УРОВНЯ ЗВУКОВОГО ДАВЛЕНИЯ, СОЗДАВАЕМОГО МОНОМОРФНЫМИ ДИСКОВЫМИ ПЬЕЗОЭЛЕМЕНТАМИ

Работа посвящена совершенствованию пьезоэлектрических преобразователей. Особое место пьезоэлектрические преобразователи занимают в электро- и гидроакустике, где они предназначены для излучения и приема акустических колебаний в воздушной или водной среде. Общей задачей при совершенствовании пьезоэлектрических излучателей является увеличение дальности их действия. Для изготовления электроакустических преобразователей используются мономорфные и биморфные элементы. Описан способ возбуждения изгибных колебаний в дисковых мономорфных пьезоэлементах. Для усиления этих колебаний в пьезоэлементе предложено создать два контура, один из которых создается таким образом, чтобы вектор электрического поля возбуждающего напряжения составлял угол с вектором поляризации, а вектор электрического поля другого контура был параллелен вектору поляризации пьезоэлемента. Это позволило повысить уровень звукового давления.

Ключевые слова: *пьезоэлектрический преобразователь, излучатель, изгибные колебания, колебательный контур.*