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EXPERIMENTAL RESEARCH OF THE MAGNETIC FLUID CONVERTER

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The article deals with the experimental research of the converter of sound oscillations into electromagnetic the active element of which is the magnetic fluid. The opportunity of functioning of magnetic fluid converter both in the field of low sound frequencies (20 – 200 Hz) and in the field of frequencies adjoining to the bottom border of an ultrasonic range (20 – 65 kHz) is shown. Transformation in low-frequency field is carried out with the help of magnetic fluid membranes, in high-frequency – on the acoustic-magnetic effect basis.

In the field of low frequencies (20 – 200 Hz) the research has been made with the use of magnetic fluid membranes (MFM).

As the geometry of a free surface of a drop of magnetic fluid (MF) essentially depends on the quantity and the degree of heterogeneity of a magnetic field [1], the research of the magnetic field of the annular magnet used in device MFM has been performed.

The theoretical analysis of the magnetic field has been also carried out on the basis of the model according to which the annular magnet is magnetized having a constant of magnetization M on volume directed along its axis. Then components of an induction of the magnetic field are defined by the formula $\vec{B} = -\operatorname{grad}\psi$ where the scalar potential looks like:

$$\psi = -\frac{M}{2\pi}\left(\int_{R_1}^{R_2} K(k_1)\frac{k_1 q}{\sqrt{qr}}\,dq - \int_{R_1}^{R_2} K(k_2)\frac{k_2 q}{\sqrt{qr}}\,dq \right). \tag{1}$$

Here $k_1 = 2\sqrt{qr/\left((q+r)^2+(z-l)^2\right)}$, $k_2 = 2\sqrt{qr/\left((q+r)^2+(z+l)^2\right)}$, R_1, R_2 – interior and exterior radiuses of the magnet, l – its half-thickness, $K(k)$ – elliptic integral of the first sort. Quantity of the magnetization was defined by value of the induction of the magnetic field measured in the centre of the magnet.

On Figs. 1 *a)* and *b)* isolines according to axial H_z and radial H_r components of the magnetic field are shown. The continuous line limits a section of the field inside the tube.

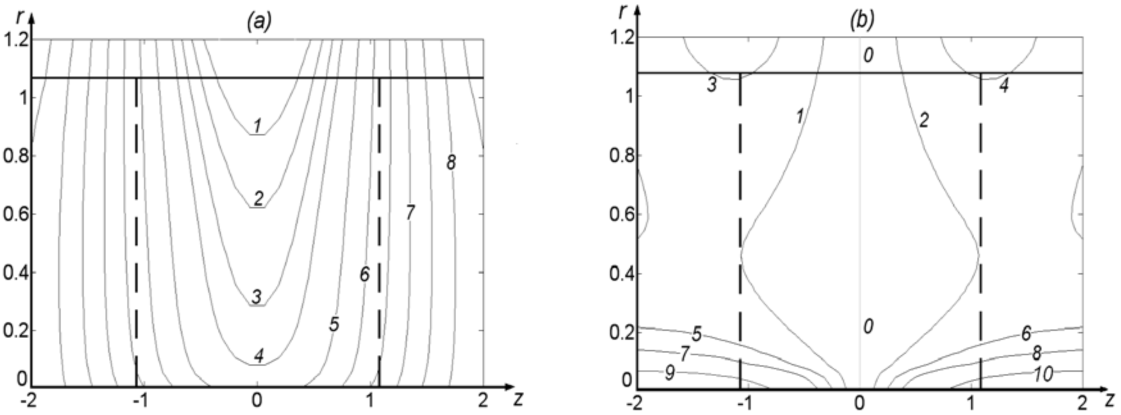

Fig. 1. a) isolines of the axial projection of an induction of a magnetic field: 1 – 90, 2 – 86, 3 – 81, 4 – 77, 5 – 68, 6 – 60, 7 – 42, 8 – 25 (mTl); b) isolines of the radial projection of an induction of a magnetic field: 1 – -3; 2 – 3; 3 – -7, 4 – 7, 5 – -7, 6 – 7, 7 – -10, 8 – 10, 9 – -23, 10 – 23; 11 – 0 (mTl).

Thus, the magnetic field in borders of the drop contour (dotted line) is mainly directed along the axis of the annular magnet, i.e. the axial component of field H_z is prevailing; in the radial direction small growth H_z is observed; the radial component of field H_r is absent in plane $z = 0$ and tends to increase in the vicinity of the axis.

The approach of the "low-magnetic" environment accepted in [2-4], and marked features of geometry of the magnetic field in a zone of an arrangement of the crosspiece, testifying a determining role in ponderomotive elasticity formation of the axial component of magnetic field H_z, are used for calculation of ponderomotive elasticity factor [5].

In the methodical attitude one of the most important questions is the establishment of borders of a dynamic range. An experiment with magnetic fluid membrane (MFM) has been made to find the latter; its device being described in [4]. Magnetic fluid crosspiece blocks the section of the tube being the neck of the glass flask in volume 0,5 *l*. At rise of the flask on height Δz above a support and its fixation in this position by soft pressing, the crosspiece is displaced concerning the position of equilibration on δz, that is

$$\delta z = \frac{k_g}{k_g + k_p} \Delta z, \tag{2}$$

here k_g – elasticity of the gas cavity, k_p – elasticity of ponderomotive type.

At sharp returning the flask in a starting position due to inertness the crosspiece appears to be displaced concerning the position of equilibration, it predetermines the development of the oscillatory process. At the moment of passage of position of equilibration by the crosspiece maximum value EMF– ε_m is fixed. Sharp moving of the flask is achieved under the influence of the impact. MF used in mechanical engineering, representing the colloid solution of one-domain particles of magnetite Fe_3O_4 in kerosene (MF-1 and MF-2) are applied. Physical parameters of magnetic colloids are shown in Table1.

Table 1

Sample	ρ, kg/m^3	η_s, Pa·s	M_s, kA/m	χ
MF-1	1294	$3{,}2\cdot10^{-3}$	52±1	6,2
MF-2	1499	$8{,}1\cdot10^{-3}$	60±1	7,5

Here: ρ – is density MF, χ – an initial magnetizability, η_s – colloid static shift viscosity. The listed parameters were defined by standard methods.

On Fig. 2 the dependence $\varepsilon_m(\Delta z)$ received for MFM on the basis of colloid MF-2 is shown. Under the conditions of the given experiment the height of the cargo falling h'=20,3 mm. Temperature is T=21 ± 0,5°C. Linear approximation is executed with the use of the program MS Excel. At $\Delta z \geq 3{,}5$ mm for MF-2 and $\Delta z \geq 4{,}5$ mm for MF-1 backlog of dependence $\varepsilon_m(\Delta z)$ from the linear is observed.

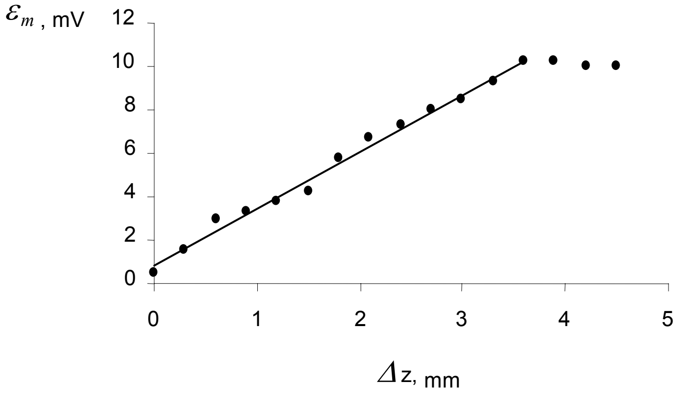

Fig. 2. Dependence $\varepsilon_m(\Delta z)$

Let's term device β – a tangent of an angle of an inclination of an approximated line as sensitivity (to displacement), and value of first oscillation's amplitude at $\Delta z=0$ as the initial impulse

ε_{m0}. In Table 2 values β and ε_{m0}, received from the experiment with various height of the cargo falling h' are shown.

Table 2

Colloid	h', mm	β, mV/mm	ε_{m0}, mV	Colloid	h',mm	ε_m/h', mV/mm	ε_{m0}, mV
MF-1	9,0	4,64	0,5	MF-2	10,8	2,53	0,75
	14,6	4,88	0,5		20,3	2,62	0,50
	19,4	5,32	0,5				

The parameter β increases almost in 2 times if to use colloid MF-1 instead of more concentrated colloid MF-2. It is possible to assume, that the specified result is caused by the negative role of viscous friction's forces due to which the amplitude of initial displacement of the crosspiece from the position of equilibrium at the moment of drawing of impact is decreased.

In the field of high frequencies (20 – 65 кHz) research was made on the acoustic-magnetic effect basis (AME) [6]. The diagram of an experiment on studying AME in a rotating magnetic field is shown in Fig.3.

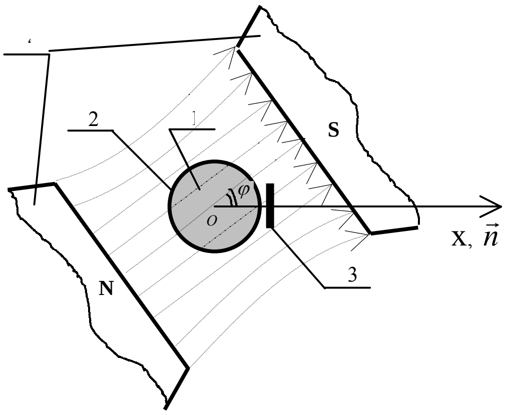

Fig. 3. The diagram of experiment

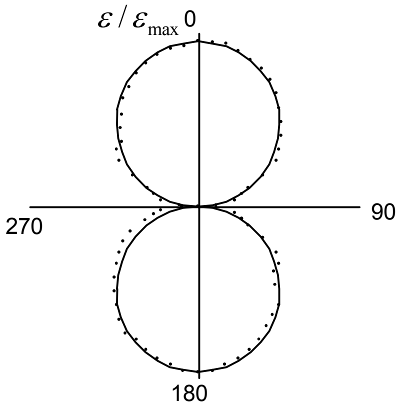

Fig. 4. Dependence of relative amplitudes AME on angle φ

Dependence of amplitude induced by EMF on the angle φ in relative units is presented in Fig.4. The thin line shows the graphic $\cos\varphi$.

Let's receive the ratio describing dependence of amplitude AME upon the angle φ, limited to a case when the flat monochromatic wave along the axis of tube 2 is extended in MF 1. The axis of the tube is located vertically. The length of the wave exceeds radius of the tube $\lambda >> R$ and $R >> \sqrt{S}$. The induction coil 3 has geometry of a rectangular and is in closed proximity to an external surface of a tube with an air-gap so there is an opportunity of free moving. The normal to a frame $\vec{n}$ in its center passes through the axis of the tube. The permanent magnet 4 is installed giving an opportunity of rotation around the axis of the tube.

The magnetic flux through a circuit, containing N_k turns, can be written down as follows

$$d\Phi = N_k \cdot S \cdot \left(\delta\vec{B} \cdot \vec{n}\right), \tag{3}$$

where S – the average area of a turn, $\vec{B}$ – a vector of a magnetic induction, $\vec{n}$ – an individual normal to a plane of a circuit.

As

$$\delta\vec{B} = \mu_0 \cdot (\delta\vec{M} + \delta\vec{H}), \tag{4}$$

and

$$\delta H = -R \cdot \delta M, \tag{5}$$

where M – magnetization, and R – demagnetization factor,

$$d\Phi = \mu_0 \cdot N \cdot_k S \cdot \left(1-R\right) \cdot \delta M \cdot \cos\varphi . \qquad (6)$$

Amplitude EMF, induced in a circuit:

$$\varepsilon_0 = \mu_0 \cdot \omega \cdot N_k \cdot S \cdot (1-R) \cdot (\beta_\upsilon \mu_0 + \gamma M_T) \cdot \xi_m \cos\varphi , \qquad (7)$$

where $\xi_m = f(z)$ – amplitude of particles displacement in a standing wave, μ_0 – magnetic constant, ω – circular frequency of fluctuations, β_υ – relative speed of movement of particles, γ – the factor taking into account thermal expansion of the fluid, M_T – temperature factor of magnetization.

Thus, during only one revolution of a magnet the amplitude, following the change of $\cos\varphi$, accepts the maximum value twice and is twice equal to zero.

Fig.5 presents curve 1 – experimentally received dependence of the cross component to the tube of magnetic intensity upon distance along the axis; curve 2 – dependence EMF of an induction ε on the distance measured along the axis of the tube.

The dependence of amplitude EMF of an induction ε_0 on amplitude of a voltage of variable EMF going to piesoelement U is shown in Fig.6.

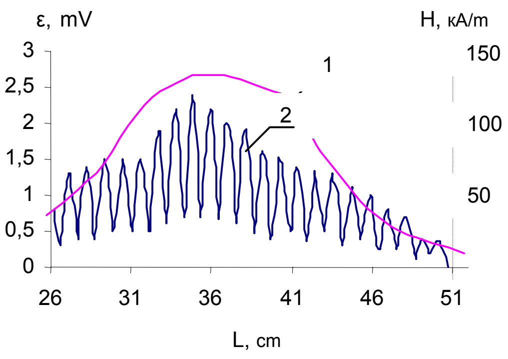

Fig.5. Dependences $H(L)$ – curve 1 and $\varepsilon(L)$ – curve 2.

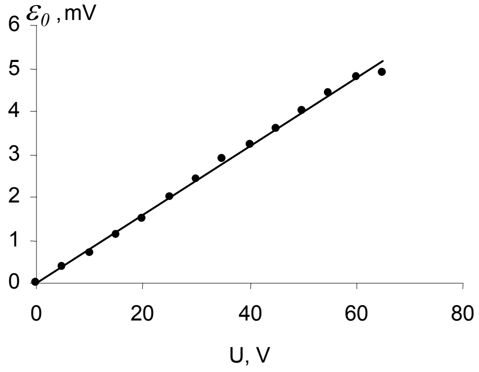

Fig.6. Dependence $\varepsilon_0(U)$.

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