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ON MOTORIZATION, VEHICLE OPERATION,
ENERGY EFFICIENCY AND MECHANICAL ENGINEERING

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Research and Determination of Effective Parameters for Acoustic Technological Environment

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Summary. The application of different models that take into account the rheological properties of the medium under the action of the load. The estimation methods of acoustic processing technology environments, dispersing, emulsification, dissolution, homogenization, degassing, extraction. They are dominant in the processing technology of dispersed media. It is noted that the effectiveness of processes determined by the parameters of ultrasonic action physical properties of the medium. Investigated parameters of acoustic apparatus, which realize the transfer of energy to the environment. Special attention is devoted to studies conducted assessing the impact on the viscosity of the medium flow acoustic parameters of the process. The possibility of using two physical models: frequency-dependent and frequency independent. Analytical dependence for determining the effect of viscosity of the medium on parameters of acoustic flow process. Found that the viscosity decreases with increasing maximum radius of cavitation bubbles. This is an important result. It confirms the need to consider the viscosity as a key parameter that significantly affects the energy cavitation process. For energy technology approach viscosity dispersion medium can provide a comprehensive measure of the dissipation of mechanical energy or mechanical energy dissipation degree of cavitation environment. Scattering energy in cavitation field affects the formation of cavitation bubbles region, stages of development, slamming, leads to an increase in ambient temperature. Indicated that the absorption coefficient characterizes the change in specific energy and intensity ultrasound in exposed environments. It is considered the absorption coefficient criterion for evaluating the effectiveness of the process of processing the acoustic environment. Evaluation of elastic-inertial properties of the environment in the process flow cavitation caused by accurate knowledge propagation velocity of sound. Experimental studies have established numerical value of the speed of sound propagation in different rheological properties. Changing the speed of wave propagation and a sharp drop in density due to the formation of cavities in the environment leads to a substantial reduction of its impedance, which accounted for at-assigned parameters and modes cavitation device. Research has identified the need to consider a mathematical model of the environment at the stage of (development stage) cavitation field as a system with distributed parameters. Changing the speed of wave propagation and a sharp drop in density due to the formation of cavities in the medium leads to a significant reduction of its impedance, which accounted for at-assigned parameters and modes cavitation device. Research has identified the need to consider a mathematical model of the environment at the stage of (development stage) cavitation field as a system with distributed parameters. Changing the speed of wave propagation and a sharp drop in density due to the formation of cavities in the environment leads to a substantial reduction of its impedance, which accounted for at-assigned parameters and modes cavitation device. Research has identified the need to consider a mathematical model environment during formation (development stage) cavitation field as systems with distributed parameters.

Key words: technological environment, the model performance sound, efficient options, viscosity, velocity of wave energy intensity.

INTRODUCTION

In modern conditions of different technologies method of acoustic processing technology media plays an important role.Therefore, a number of treatment methods and new materials, which include methods of dispersing, emulsification, dissolution, homogenization, degassing, extracting implemented acoustic method.

Dispersion, is generally regarded as the destruction of monolithic particles or breach connection between the particles. Obviously, these two processes depend on the physical, chemical and mechanical properties of initial components of the technological environment. These properties in turn affect the value of the threshold intensity, the speed of the process, as well as qualitative and quantitative parameters of dispersion. The process of dispersing the presence of acoustic cavitation is caused by a mechanism that consists of two stages [1]. The first stage of demolition material under the action of shock waves that occur when cavitation bubbles slamming, and the second under mikrostruyok liquid emerging at the close of nonspherical cavitation bubbles.

The advantage of a mechanism in the acoustic dispersion is caused by the original form nucleation process of cavitation bubbles. Given that the size of the cavitation bubbles larger than the solid particles to form a closed bubble shock wave. If the particle size exceeds the size of the bubbles, it loses its spherical shape and form when closing mikrostrumeni fluid [1]. Based on these assumptions, methods optimize the dispersion process should be based on the following basis: ultrasonic device parameters provide a process by which stage the maximum development speed faster slamming cavitation cavitation bubbles. In the process of dispersing solid particles also process consists of two stages. In the first stage under intense mikropotokiv generated during pulsation cavitation bubbles, pores, deepening and cracks on the surface of the particles are filled with liquid. In the second stage, the cracking of the particles under the influence of shock waves generated in the fluid at the close of cavitation bubbles.

Ultrasound emulsification, as the transition from one environment mutually insoluble liquids in dispersed state in a different environment offers you highly, almost chemically pure and homogeneous emulsion. There are two approaches to explain the mechanism of occurrence ultrasound emulsification. In one approach, the physical mechanism of cavitation bubbles emulsification process is carried out in one of the liquids near two phases in the closing stages captures and separates droplets of the total weight of other liquids. In another approach emulsion formation carried collapse into a drop of cumulative jets formed by closing the asymmetric cavitation bubbles.

Dissolution - a heterogeneous physico-chemical interaction of solid and liquid accompanied by a transition phase in solid solution. With the use of ultrasound as a treatment method, much faster dissolving substances. By dissolving be received various water, alcohol, oil solutions crystalline substances, solvents, dry and thick extracts, syrups, pigments and so on. D.

Homogenizing process as the manufacturing process is carried out over a two-phase or multiphase system, thus decreasing the degree of heterogeneity of distribution of materials and phases throughout the volume. Homogenization is used as the processing, mainly in the chemical industry for Macromolecular and for macromolecular compounds. Homogenization in some way different from the dispersion process because excluded grinding process. However, there are similarities between these processes them when it comes to processing ultrasonic waves milk. Efficiency homogenization confirmed in the study of influence of ultrasonic waves in aqueous polyvinyl alcohol.

Degassing, a process that involves the allocation of emissions from a variety of solutions. For physical phenomenon is the diffusion of dissolved gas in the cavitation bubble that having buoyancy quickly rises to the surface and leaves the liquid. Ultrasonic degassing liquid media used to isolate gases from solutions of plant and transformer oil, viscose, sauces and other media. Use this method for treating alloys of impurities in the lubricants they remove dissolved oxygen. An important parameter that determines the efficiency of this method is the consideration of the viscosity of the medium.

Extraction process of extracting a solid or liquid substances complex of one or more of its components, the most effective is the use of ultrasound. Earlier studies [2] proved high efficiency of extraction of pectin. This occurs not only significantly speed up the process extracting the necessary materials, but also increase, compared with other methods of extraction, the main product output.

Based on the physics examination process of different processing methods process fluids can be noted. The effectiveness of processes for the use of ultrasonic cavitation technology is determined by ultrasound treatment regimens (frequency and amplitude of sound pressure) and the physical properties of the medium, such as density, surface tension and rheological properties (elasticity, viscosity). In most of the physical and chemical processes use ultrasound treatment of liquid media technology developed due to the occurrence of cavitation treatment and related phenomena: the shockwaves, mikrotechiyi, one speaker bulentnist. There are similarities ultrasonic treatment processes of various technological mediums together. However, an important aspect of treatment is the problem of establishing classifications by viscosity process fluids, assessing their impact on processing. Face the problem is the possibility of using physical models dispersed environments to determine their rational use. Therefore, to determine methods research is needed to evaluate existing research in solving these problems.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The effectiveness of the introduction of acoustic oscillations in unlimited and limited environment should be ensured by matching the value of the input impedance of the source medium fluctuations (converter) and represent a single wave system [3]. For environments with variable parameters may vary extinction coefficient of waves and wave propagation speed, which is typical mode developed cavitation.

An important parameter that has a significant effect on these parameters is the viscosity of the process medium. Effect of viscous properties of process fluids to form bubbles and to determine the parameters drawn attention [4-9]. For example, in [7] driven schedule changes reduced the resistance of the square of the velocity oscillations (Fig. 1).

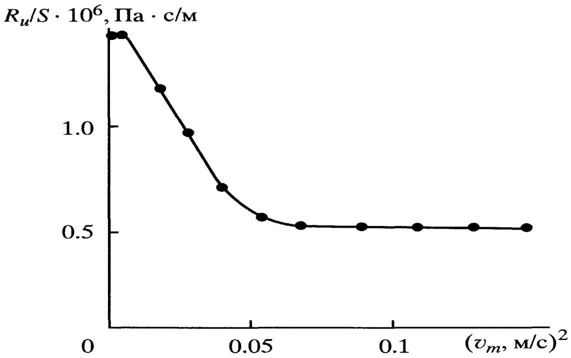


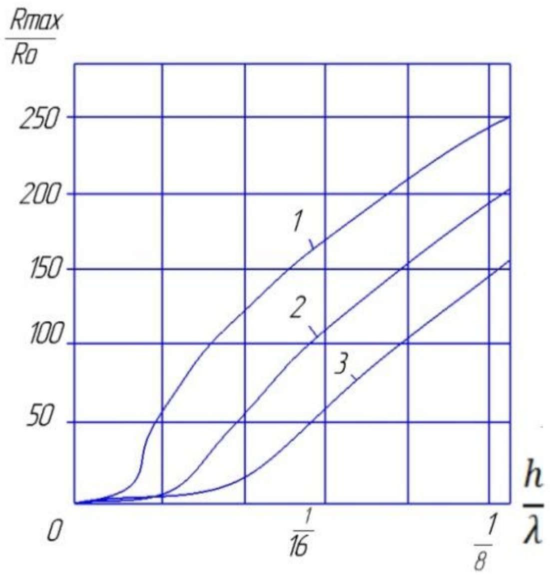
Fig. 1. Change the reduced resistance of the square of the velocity fluctuations

From the graph it follows that the resistance significantly affects the process of cavitation and significantly changing especially in the initial stage of cavitation treatment. In another study[10] observed thatthe propagation of sound in the liquid, bubbles that oscillate at a frequency close to resonance, causing significant attenuation of sound energy. Comparing the degree of influence of viscosity and surface tension of the implementation process of cavitation (Figure 2) given in [11].

As follows from the graphs, the viscosity significantly higher than the surface tension of the liquid in the degree of impact on the value of the threshold thickness. With the increased viscosity decreases the maximum radius of cavitation bubbles. This is an important result. It confirms the need to consider the viscosity as a key parameter that significantly affects the energy cavitation process.Thus, the energy dissipation in the cavitation area somehow influences the formation of cavitation bubbles region, stages of development, slamming, leads to an increase in ambient temperature. This fact pointed out in [6] (Fig. 3).

Theory of media behavior, considered as a viscous liquid, based on Newton's model [12], which establishes a linear relationship between stress and corresponding adjacent irreversible shear deformation rates, describes a model of the environment as linear viscous fluid in the absence of process its compression. Linear models meet only simple liquid. More complex structure of liquid, such as solutions, dispersion fluid system in most cases the flow curve, distinct from Newton. Currently, there are many semi-empirical and empirical rheological models, among which are the according to [13], most commonly used in research models - psevdoplastychni ("purely viscous") environment and viscoplastic medium, describes various laws flow.

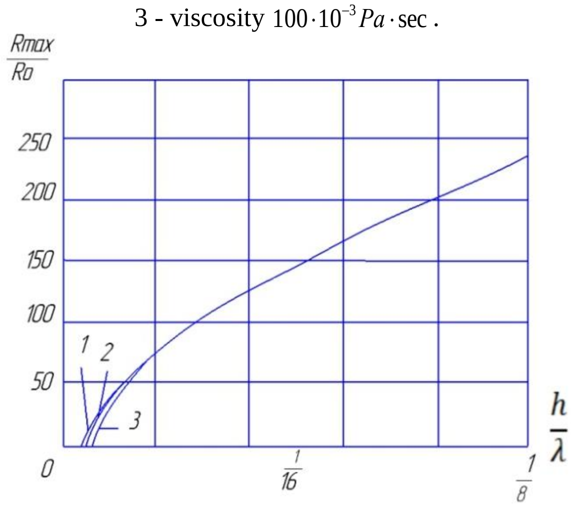
Considering methods for determining the viscosity, it should be noted, according to the process of ultrasonic cavitation processing methods is to use the closest one of the sections of phenomenological rheology, which unlike mikroreolohiyi and makroreology, rheological studies bordering on physics and chemistry, as cavitating state of the environment is inextricably floor ' related parameters of the process. In this process, the main difficulty of accurately determining the viscosity is the classic way to use viscometer for Plastometers [14] provides the possibility to divide the property owned electrical and technological environment, and in a real change of rheological properties under ultrasound reflected in experimental set an "device - environment" virtually impossible.



1 - viscosity $1 \cdot 10^{-3}$ $Pa \cdot \sec$;

2 - viscosity $30 \cdot 10^{-3} Pa \cdot \sec$;

3 - viscosity $100 \cdot 10^{-3} Pa \cdot \sec$.

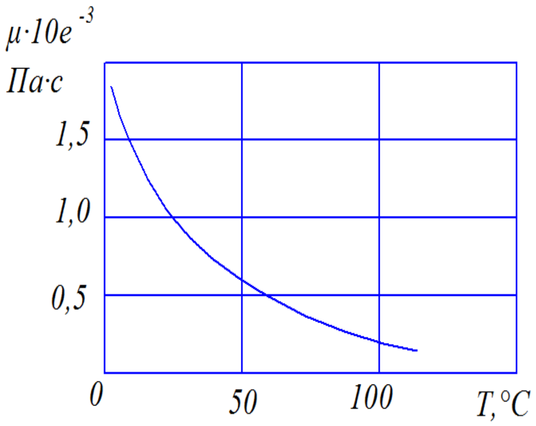


1 - surface tension 150^{-3} N / m;

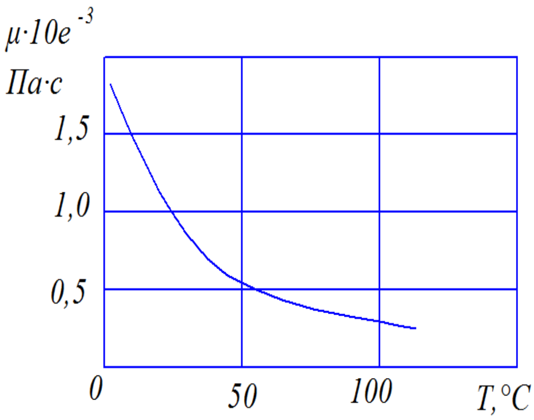
2 - surface tension $72^{-3} N / m$;

3 - surface tension $1^{-3} N / m$.

Fig. 2. Effect of viscosity (a) and surface tension (B) depending on the radius of cavitation bubbles on the thickness of the liquid



a)



b)

and - water; b - ethyl alcohol (96%)

Fig. 3. The dependence of the viscosity of the medium temperature.

For energy technology approach viscosity dispersion medium can provide a comprehensive measure of the dissipation of mechanical energy or mechanical energy dissipation degree of cavitation environment. The analysis [15] showed that the rate of extinction of acoustic waves into account:

– viscous resistance force between adjacent particles environments that have different speeds;

– losses arising during full compression of the environment;

– loss, causing floated heat.

The first component of the energy dissipation occurs with exposure of internal friction acting on the particle environment in which distributed acoustic wave. The basis of the second component of the energy dissipation is relaxation process that affects the absorption of waves in a limited strip of frequencies. The third component of energy dissipation is a heat transfer area of compression in the region dilution of the acoustic wave.

The analytical expression for determining the attenuation coefficient obtained by solving wave equation environment with regard to energy dissipation in which a complex wave number consisting of real and imaginary parts, which makes it possible to get the extinction coefficient:

$$\alpha = \frac{\omega^2}{2\rho_0 c^3_{зв}}\left[\frac{4}{3}\eta + \eta' + \chi\left(\frac{1}{c_\upsilon} - \frac{1}{c_p}\right)\right], \qquad (1)$$

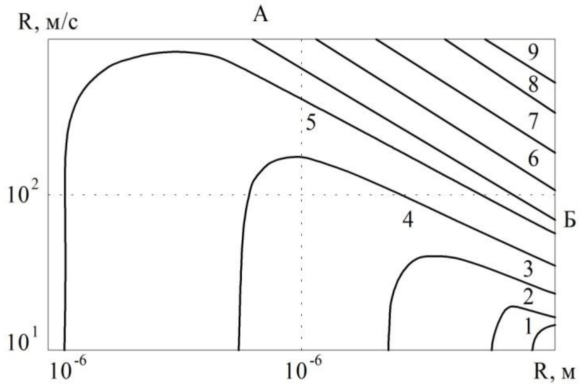
where ω - frequency of CFS - the speed of wave propagation; ρ_0 - density; η, η' - viscosity shear and bulk viscosity; χ - thermal conductivity; c_υ, c_p - gas specific heat at constant volume and constant pressure, respectively.

The degree of the impact of reduced component determined by the specific process processing technology environment. Overall, it is worth noting the total dependence of the damping of waves followed by absorption of the acoustic wave is proportional to the square of the frequency and inverse proportion to the speed of its spread. The lion's share of energy dissipation depends on the coefficient of shear viscosity. Several studies [1, 4, 16] in the research process and the formation of cavitation bubbles slamming in equations account for viscous member according to this or that hypothesis friction. For environments that are subject to change linear voltage displacement from velocity gradient presented as Newtonian fluid environment [14] and by non-linear change of shear stress velocity gradient is dylatantna, psevdoplastychna and binhamovska liquid.

The process of ultrasonic dispersion and a number of other processes in most cases held in liquids with low viscosity, but some chemical-technological processes occurring in environments with high viscosity. Therefore the investigation of cavitation in viscous media paid more attention [17]. If the coefficient of viscosity, viscosity close to water ($\mu = 10^{-3} Pa \cdot \sec$), The effect of viscosity on slamming cavitation bubbles is negligible, while the viscosity $10^{-2} - 10^{-1} Pa \cdot \sec$, The effect of viscous forces are beginning to affect the behavior of cavitation bubbles. By increasing the viscosity of 1 Pa · s, which corresponds to the viscosity of glycerol at room temperature, the bubbles do not zahlopuyutsya and become pulsating [17]. Another feature is a viscous liquid of high hazovmist ($\delta = 0{,}005$), Which explains the low speed ascent and removal of gas bubbles from the liquid. The constant presence of relatively large bubbles of gas in the narrow fluids (such as glycerol) it greatly reduces cavitation strength.

Effect of viscosity and fluid compressibility growth and cavitation bubbles slamming theoretically investigated in many studies [7, 18, 19]. In these studies the viscous term in the equation that describes the radial motion of bubbles counted only after boundary conditions. Therefore, the ratio between the viscous member in the equation of motion and the Member States, taking into account the compressibility requires clarification. In [7] was estimated effect of viscosity and compressibility of the environment on the dynamics of cavitation bubbles using a differential nonlinear equation of Navier-Stokes equations, taking into account the sliding volume and viscosity. Taking these numeric values of:

$P_\infty \approx 10^5 N/m^2$, $P_m \approx 10^5 N/m^2$, $R_0 = 10^{-5} m$, $2\sigma / R_0 = 10^4 N/m^2$, $4\mu\dot{R}/R \approx 4 \cdot 10^7 N/m^2$, It was found that when R ≤ 10-5 m, μ ≥ 1 Pa · s, R≥ 100 m / s sticky member of two orders of magnitude more than the rest. The result of the decision is a graph of compression velocity vacuum bubbles in a viscous fluid (Fig. 4).



Curve 1 - speed - 12 m / s; 2 - 15; 3 - 20th; 4 - 50; 5 - 80; 6 - 110; 7 - 200; 8 - 500; 9 - 800 m / s

Fig. 4. The speed compression vacuum bubbles in a viscous fluid (μ = 1Pa · s) under the action of inertial forces [7].

From the charts (see Fig. 4) it follows that for a certain coefficient of viscosity when dependent $R = \varphi(R)$ expressed by a straight line (line AB), which is below the range of values $R, \dot{R}_1$. Process slamming bubbles occurs. In the fall, when the parameters are located below the line AB, the rate slamming bubbles first matter that was different from usual. Further carried hopping speed where the process slamming bubbles are reduced. This is because if at some point the action of viscous forces is inertia, is slowing down the process of cavitation.

The analysis of the degree of influence of modified components of the acoustic system and rheological characteristics of the technological environment determined by the specific process of processing environments. It should be noted the total dependence of the damping of the waves on the parameters of the process. These parameters are the oscillation frequency of the acoustic system, the speed of wave propagation in the medium, the pressure and intensity as an integral assessment of the effectiveness of the process. On this basis and determined purpose and objectives of research.

OBJECTIVE

The purpose of research is to determine the effective parameters of acoustic processing technology environments with different rheological properties. To achieve the designated goal formulated the following tasks:

- development of physical and mathematical model of the system "cavitator - technological environment";
- research viscous and elastic properties of the technological environment and setting their numerical values;
- explore energy absorption coefficient and install it and depend on parameters of ultrasonic vibrations.

THE MAIN RESULTS OF THE RESEARCH

Research viscosity influence on the formation of cavitation bubbles slamming and dedicated several works [4, 20, 21], where this effect is taken into account in the equation of motion. In certain visco-plastic properties of the process environment during processing was applied as a rule, viscous hypothesis, called - chastotozalezhna model. According to this hypothesis change in viscosity is most common Kelvin-Voigt model [14]. In which the relationship between stress and deformation ε σ is:

$$\sigma = \mathrm{E}\varepsilon + \eta\dot{\varepsilon} \qquad (2)$$

where η - coefficient accounting viscous properties; E - modulus of elasticity; $\dot{\varepsilon}$ - speed of deformation. Dependence (2) different from the usual elastic body applied before[22] Hooke's law in the form σ = Eε, taking into account the dissipative component, which is a function of strain rate $\dot{\varepsilon}$.

Wave equation viscous-elastic medium (2) has the form[14]:

$$\frac{\partial^2 x}{\partial t^2} = \frac{E}{\rho}\frac{\partial^2 x}{\partial z^2} + \frac{\eta}{\rho}\frac{\partial^3 x}{\partial x^2 \partial t} \qquad (3)$$

Decision equation (3.2) is a function of:

$$x = A_0 e^{\pm\alpha z + i(\pm kz - wt)} \qquad (4)$$

where x - layer moving manufacturing environment amplitude fluctuations A0; α - wave attenuation coefficient in an environment that is exposed to acoustic apparatus; k - wave number (k = ω / c) z - coordinate the direction which extends wave.

The most important characteristics of equation (3) and its solution (4) are the elastic modulus E environment in a particular stage of processing and the drag coefficient η, Which defines the property bundle technological environment. Substituting the solution (4) to (3) subject to (2) after simple transformations we obtain an expression for determining the coefficient of resistance:

$$\eta = 2E\frac{\alpha}{c\left(k^2 - \alpha^2\right)}. \qquad (5)$$

The magnitude of the resistance factor η influences the extinction coefficient α waves in an environment that is exposed to an acoustic device, the wave number k (k = ω / c) and medium modulus E, which is defined by the relationship:

$$E = \frac{\rho\omega^2\left(k^2-\alpha^2\right)}{\sqrt{\left(k^4-\alpha^4\right)^2+4k^2\alpha^2\left(\alpha^2+k^2\right)^2}} \tag{6}$$

There is another hypothesis[19]At which the dissipative component is a function of the amplitude of movement. The relationship between stress and deformation unlike (2) appears in a slightly different way:

$$\sigma = E\varepsilon + iE\varepsilon\gamma \tag{7}$$

where - the imaginary unit, indicating the rotation vector component of dissipative $E\varepsilon\gamma$ relatively resilient $E\varepsilon$ an angle $\pi/2$; γ - drag coefficient, which assesses the level of energy dissipated in the environment in one cycle fluctuations. That is, the drag coefficient is a function of strain amplitude and power dissipation as in equation (3) in the direction directed in the opposite referral rate. Determination of γ and its physical nature is given below (see. Hysteresis loop method).

Wave equation, prepared in accordance with the relationship (7) is:

$$\frac{d^2x}{dt^2} = c^2(1+i\gamma)\frac{d^2x}{dz^2} \tag{8}$$

Decision equation is determined by complex wave function (9):

$$x(z_1 t) = X_0 e^{i\left(\omega t - k^* x\right)} \tag{9}$$

where κ^* - complex wave number,

$$\kappa^* = \omega/c\,(\alpha + i\beta). \tag{10}$$

The coefficients α and β obtained by substituting (9) (8) taking into account (10) after simple transformations is as follows:

$$\alpha = \sqrt{\frac{\sqrt{1+\gamma^2}-1}{2\left(1+\gamma^2\right)}};$$

$$\beta = \sqrt{\frac{\sqrt{1+\gamma^2}+1}{2(1+\gamma^2)}} \tag{11}$$

The coefficient α determines the rate of extinction wave and β affects the length of the same wave. Indeed, if not take into account energy dissipation ($\gamma = 0$), Then as follows from (11) $\alpha = 0$ and $\beta = 1$. This indicates that the wave propagating in the environment without fading and then opposed (10), the wave number k is: $\kappa = \omega/c$ corresponding to models perfectly elastic body.

The speed of wave propagation with that part of the equation (8), the elastic different from the environment in which p = E / ρ, is:

$$c^2 = \frac{E^*}{\rho} = \left(\frac{\omega}{\kappa^*}\right)^2 = \frac{\omega^2}{(\kappa - i\alpha)^2}, \tag{12}$$

where $E^* = E' + iE^*$ - complex modulus environment; E', E'' - real and imaginary part of the complex modulus; ρ - density environment; α - coefficient of extinction wave.

Equation (8) can be solved relatively wavenumber ω/c and absorption coefficient α, or relatively true E' and the imaginary part E'' complex modulus.

With respect to the wave number ω/c and absorption coefficient α receive:

$$\omega/c = \sqrt{\frac{(\varphi-1)\rho\omega^2}{2\varphi^2 E'}};$$

$$\alpha = \sqrt{\frac{(\varphi+1)\rho\omega^2}{2\varphi^2 E'}};$$

$$\left(\varphi = E''/E'\right) \tag{13}$$

Regarding the actual E' and the imaginary part E'' complex modulus:

$$E' = \frac{\left(1-\alpha^2 c^2/\omega^2\right)\rho c^2}{\left(1+\alpha^2 c^2/\omega^2\right)^2};$$

$$E'' = \frac{2\rho c^2 \alpha\, c/\omega}{\left[1+\left(\alpha\, c/\omega\right)^2\right]^2}. \tag{14}$$

The formula importance is the ability to determine the numeric value of the absorption coefficient α. You must have velocity c of wave propagation, numerical value of medium density ρ at any given occurrence of this or that stage of cavitation processing environments and complex modulus. Interesting results for the analysis of complex elastic modulus (14) is a condition: ($\alpha^2 c^2/\omega^2$ << 1) by which among the possible case of small effect of the attenuation on wave propagation in the medium. Then expression (14) will look like:

$$E' = \rho c^2; E'' = 2\rho c^2 \alpha\, c/\omega.$$

To determine the coefficient of absorption, taking into account factors: the volume and viscosity shear viscosity, thermal conductivity, specific heat of gas at constant volume and constant pressure can be used the following dependence[19, 23]:

$$\alpha = \frac{\omega^2}{2\rho_0 c^3_{xв}}\left[\frac{4}{3}\eta + \eta' + \chi\left(\frac{1}{c_\upsilon} - \frac{1}{c_p}\right)\right], \tag{15}$$

where ω - frequency, $c_{xв}$ - speed of wave propagation; ρ_0 - density; η, η' - viscosity shear and bulk viscosity; χ - thermal conductivity; c_υ, c_p - gas specific heat at constant volume and constant pressure, respectively.

Whatever changes shear stress on the velocity gradient to determine the absorption coefficient can be used equation [21]:

$$\Delta p = \frac{1}{c_0^2}\frac{\partial^2 p}{\partial t^2} = -\rho_0 \frac{\partial^2 \Delta v}{\partial t^2}; \tag{16}$$

where p - instantaneous pressure environment; c_0 - speed of sound in the environment; t - time; ρ_0 - density environment; Δv- instant volume content of bubbles.

Equation (16) describes the acoustic field distribution in medium containing cavitation bubbles, which are filled with vapor or gas. Given that fluctuations cavitation bubbles are nonlinear, there is a need to take into account higher harmonics. In this case, the sound pressure and instant volume content of bubbles under the terms of mathematical physics can be represented as a Fourier series in complex form [24]:

$$\bar{p}(r,t)=\sum_{n-1}^{\infty}\bar{p}_n(r)e^{-in\omega t};$$

$$\bar{v}(r,t)=\sum_{n=1}^{\infty}\bar{v}_n(r)e^{-in\omega t}, \qquad (17)$$

where - the imaginary unit, n - number of harmonics; ω - circular oscillation frequency acoustic device, which is transmitted to the technological environment; r - radius vector of point environment.

After substituting (17) into the wave equation (16) we obtain the equation for any - any harmonics:

$$\Delta\bar{p}_n+\frac{n^2\omega^2}{c_0 2}\bar{p}_n=n^2\omega^2 p_0\bar{v}_n. \qquad (18)$$

For the primary harmonic equation (18) is:

$$\Delta\bar{p}_1+\frac{\omega^2}{c_0 2}\left(1-\frac{p_0 c_0 2\bar{v}_1}{\bar{p}_1}\right)\bar{p}_1=0 \quad (19)$$

Equation (19) after appropriate designations real and imaginary parts through wave number cavitating medium and the absorption coefficient cavitating environment will look in a more compact form:

$$\Delta\bar{p}_1+(K+i\alpha_*)^2\bar{p}_1=0 \qquad (20)$$

where K - wave number cavitating environment, and - absorption coefficient cavitating medium.α_*

Thus, from equations (19) and (20) we obtain the absorption coefficient:

$$a_*=-\frac{\omega}{c_0}\mathrm{Im}\frac{\rho_0 c_0 2\bar{v}_1}{\bar{p}_1}; \qquad (21)$$

Thus, the absorption coefficient (21) depends on the angular oscillation frequency of the acoustic system, the speed of wave propagation in the medium, the sound pressure cavitating medium and the volume content of cavitation bubbles.

Due to the dependence of intensity $I=\frac{p^2}{2pc}$ relations (21) can be written as:

$$a_*=-\frac{\omega}{c_0}\mathrm{Im}\frac{\rho_0 c_0\ \ 2\bar{v}_1}{(\sqrt{2\rho cI})e^{i\varphi}};I=\frac{|\bar{p}_1|^2}{2\rho c};\bar{p}_1=|\bar{p}_1|e^{i\varphi} \quad (22)$$

where φ - phase shift between the real and the imaginary parts of the ultrasonic pressure $\bar{p}_1$.

In an environment which applies ultrasound, pressure and temperature changes in the environment that divided its dynamic equilibrium. The process of establishing equilibrium accompanied by dissipation of wave energy, ie sound absorption. Most of the absorbed energy is converted into heat, a smaller portion is in the environment irreversible structural changes. Energy absorption is the result of particles rubbing against each other. This process is due to internal friction, thermal conductivity absorbing medium and its structure. In different environments energy absorption properties different. Also energy absorption depends on the parameters of ultrasonic vibrations. Analysis of the above dependency relationship indicative of the intensity I Ppyt specific energy and energy absorption coefficient a:

$$a = Ppyt\,/\,I \qquad (23)$$

Thus the absorption coefficient and, as it demonstrates the dependence (23). Not only characterizes the change in specific energy Ppyt. and ultrasound intensity I in irradiated environment, and can serve as a criterion for evaluating the effectiveness of the process of processing the acoustic environment. The intensity of ultrasonic vibrations in the environment decreases exponentially:

$$I=I_0 e^{-2\Delta Vnh}, \qquad (24)$$

where I, Io - intensity ultrasound waves at the surface and at depth h; δp - absorption coefficient, which depends on the frequency of ultrasonic waves, temperature and properties of the medium. The absorption coefficient δp- reciprocal one distance at which the amplitude of the sound wave comes in e times. The more δp, the more medium absorbs ultrasonic waves. Δp absorption coefficient increases with frequency ultrasound (Fig. 5).

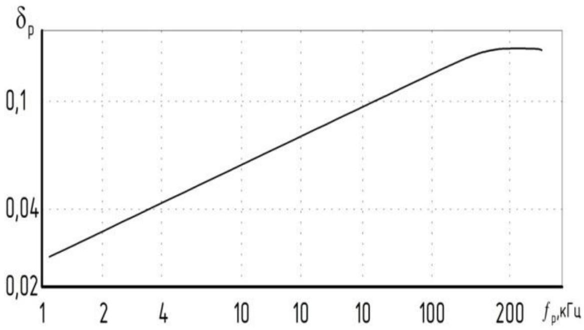


Fig. 5. Change absorption coefficient with increasing frequency ultrasound

According to the classical notions of propagation of ultrasound in liquids is supposition [25], that the propagation of waves in the fluid having relaxation processes that need some recovery time certain state [26]. The presence of these processes leads to additional energy losses than losses caused by viscosity and thermal conductivity, as noted above. This additional attenuation increases sharply when the relaxation period coincides with ultrasonic vibrations. During processing technology environments ultrasonic vibrations cavitation relaxation processes in explicit form are not captured [1, 17], although indirectly this phenomenon is present.

Analytical dependence for determining the speed of propagation of waves in the cavitating medium.

Currently, there are two main methods for measuring the speed of propagation of ultrasound waves - and interferometric pulse. Interferometric method is based on determining the length of the ultrasonic waves at a certain frequency fluctuations. Pulse method - by measuring the time interval during which the ultrasonic wave passes a certain distance.

To determine the speed of wave propagation in the cavitating medium sk usually using the formula [27]:

$$c_K = \sqrt{E/\rho}, \quad (25)$$

where E - modulus environment that has a density ρ. It velocity of the waves determines the physical meaning of resilient ratio (E) and inertia (ρ) characteristics of the environment as the measurement of some influence on the process of cavitation. If relation (25) is mainly used for elastic media, for liquids rich gas used formula [28]

$$c_K = 1\Big/\sqrt{\rho\beta_{ac}}\,, \quad (26)$$

where βac - adiabatic compression.

Provided that the cavitation medium consists of liquid distributed gas bubbles in it and is seen as a homogeneous biphasic medium with average values of density, temperature and pressure wave propagation speed can be determined by the formula [29]:

$$c_K = \rho_2 c_p^2 / [\rho_p \varphi (1-\varphi)] \quad (27)$$

where ρ2, ρp - in accordance with the density of gas and liquid; c_p - speed of sound in precavitational liquid; φ - the ratio of the volume of the gas component to the volume of gas-liquid mixture (volume of gas in liquid).

From formula (27) follows that the numerical value of the speed IC depends on the ratio of gas and liquid components as was described above.

If the formation of bubbles in the fluid being implemented as a result of thermal action formula for determining the speed of propagation has the form [29]:

$$c_K = P_m L\mu / \left[\rho_p RT (G_p T)^{1/2}\right] \quad (28)$$

where L - specific heat of phase transition; Gp - heat of the liquid; R - universal gas constant; μ - molar mass of the substance; T - temperature at which the phase transition.

In the cited works [30, 31] does not specify whether the dependence of the rate of frequency, ie whether the phenomenon manifests dispersion. On this dependence is noted in [32] that the occurrence of cavitation leads to a dispersion medium phase velocity of wave propagation. This dependence is:

$$\omega_K / c_K = \omega / c_0 (1 + 4\pi n R_0 c_0^2 / (\omega_0^2 - \omega^2 - i\mu\omega))^{1/2}, \quad (29)$$

where ω - frequency waves c_0, c_K - speed of sound in liquids without cavitation and cavitation under, n - number of bubbles per unit volume of fluid R_0 - equilibrium radius of the bubble ω_0 - bubble resonance frequency, μ - coefficient of damping vibrations of bubbles.

If the concentration of small bubbles in the liquid, ie $\left|4\pi n R_0 c_0^2 / (\omega_0^2 - \omega^2 - i\mu\omega)\right| < 1$ Expression (29) is simplified and reduced to the following:

$$\omega_K / c_K = \omega / c_0 (1 + 2\pi n R_0 c_0^2 / (\omega_0^2 - \omega^2 - i\mu\omega)) \quad (30)$$

Provided that the frequency range $\omega < \omega_0$ ($\mu < \omega_0$):

$$\omega_K / c_K = \omega / c_0 + ib\omega^2 + d\omega^3, \quad (31)$$

where

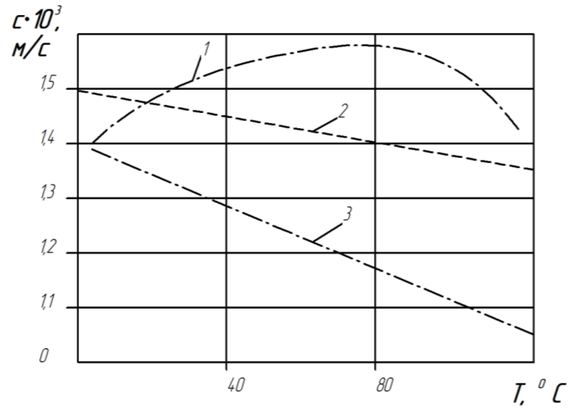
$$\left.\begin{aligned} c &= c_0 (1 + 2\pi n R_0 c_0^2 / \omega_0^2)^{-1}, \\ b &= 2\pi n R_0 c_0 \mu / \omega_0^4, \\ d &= 2\pi n R_0 c_0 / \omega_0^4, \end{aligned}\right\}$$

In [33] proposed formula for determining the rate as:

$$C^2 = \frac{R^2 C_{æ}^2 \left(\omega_0^2 - \omega^2\right)}{R^2 (1-a)^2 \left(\omega_0^2 - \omega^2\right) + 3a(1-a) C_{æ}^2}, \quad (32)$$

where $C_{æ}$ - phase speed of sound in liquid drops, $\omega_0 = \left[\left(3P_0 + 4\sigma / R\right) / R^2 \rho_{æ}\right]^{0,5}$ - frequency of resonance oscillations of gas bubbles σ - the surface tension, $\rho_{æ}$ density of liquid drops, P_0 - static pressure ω - acoustic oscillation frequency emitter.

Application dependencies (30) - (32) in real conditions of payments difficulties is the need of knowledge other than the speed of sound in liquids without cavitation and cavitation under, the number of bubbles per unit volume of fluid equilibrium radius of the bubble, its resonant frequency and the number of harmonics. In the cited paper [28] has not shown how determined natural frequency of oscillation bubbles, because so far not found a response or include one or bubbles of a certain amount. However, reduced information should be in a particular form to be taken into account. Unlike gas, where the speed of sound with increasing temperature increases due to the fact that the elasticity of gas caused by the transfer of momentum increases in liquids speed of sound decreases (2 ... 6 m / (s · degrees)) with increasing temperature (Fig. 6).



1 - water; 2 - mercury; 3 - benzene.

Fig. 6. Change the speed of ultrasound depending on the temperature

The speed of sound (see. Fig. 6) in water with increasing temperature increases with temperature coefficient $\partial c_0 / \partial T \approx 2{,}5 м/(с \cdot град)$ Reaches a maximum value $c = 1550 м/с$ at $T = 67^0 C$ And then decreased as fluids.

With the increase in static pressure the velocity of sound in water increases linearly by an amount 0,1m/(sec atm) [17]. Obviously, the choice depending(25) (26) (27) or (28) to determine wave propagation speed in technological environments requires specifying the conditions and assess technological process. This is due to the fact thatthe sources [29] powered range changes speed limits: 20 ... 100 m / s, [10] sk = 25 ... 30 m / s, and in [34] - within IC = 10 ... 12 m / s.

On the basis of the results of analysis on existing dependencies determine the speed of wave propagation in the cavitating medium for their use in further studies can be noted.

1. There is a need of experimental research for qualitative and quantitative picture of wave propagation velocity change, depending on the state of the fixed cavitating medium.

2. Obumovlena this need sharp differences in the numerical values of the speed of propagation of the waves that are listed in the literature. A possible explanation is or different methods orno fixing that part of the flow cavitation process, which determined this rate.

3. Correct the results obtained depend on the precise choice of method experimental study of viscous and elastic characteristics and parameters of technological environments.

Among the known and most common methods are the following [8, 11] method hysteresis loop, phase technique, power, spectral correlation analysis method of fading fluctuations.

A survey and evaluation of existing methods of experimental study of viscous and elastic properties allow technological environment noted.

1. The method is based on the angle dependent phase shift φ between the force or pressure in the contact system and the acoustic environment and callee their movements can be used to assess the level of energy dissipation.

2. Currently, there are two main methods for measuring the propagation velocity of ultrasonic waves, pulse and interferometric. Interferometric method is based on determining the length of the ultrasonic waves at a certain frequency fluctuations. Pulse method - by measuring the time interval during which the ultrasonic wave passes a certain distance.

3. Measuring the speed of wave propagation in the technological environment by comparing phase two signals - which are passed on through contact zone cavitator studied medium to hard limit. Phase comparison made or speakers (for transformers) or electric (in the measuring receiver) tract.

Based on the research [13, 35] defined classification technological environments for their viscosity (Table. 1).

Definition and impact viscous properties made indirect method based on the following considerations. The well-known fact is thatpropagation of ultrasound in the technological environment is accompanied by absorption of energy in it. This results in reducing peak value of sound pressure with distance from the source of ultrasonic vibrations. However,often [16, 36] Appreciate not reduce the amplitude of sound pressure and intensity ultrasonic vibrations change:

$$I(x) = I(0) \cdot e^{-2\cdot\alpha\cdot x} \quad (33)$$

where $I(x)$ - intensity ultrasonic vibrations at coordinates x; I (0) - intensity ultrasonic vibrations at the origin; - extinction coefficient of ultrasound.α

Table 1. Classification technological environments for their viscosity

Viscosity mPa.s	Classification sign	Environment
5 to 30	low viscosity	water and alcohol solution
30 to 400	secondary viscosity	lubricants
400 do1000	Cementing	polymers
from 1000 to 3000	increased viscosity	paints and varnishes
3000 to 10000	high viscosity	Epoxy resins

Accordingly, ultrasonic extinction coefficient can be calculated by measuring according to the formula [20]:

$$\alpha = \frac{1}{2\cdot(x_2-x_1)} \cdot \ln\left(\frac{I_1}{I_2}\right) \quad (34)$$

where x2 and x1 - coordinates measurements; I1 and I2 - intensity ultrasonic vibrations in the respective points of measurement. The intensity ultrasonic vibrations associated with the amplitude of the sound pressure ratio,

$$I = \frac{P^2}{2\cdot\rho\cdot c} \quad (35)$$

where R - amplitude of sound pressure; ρ - density; with - speed of sound.

Assuming that the change in density and speed of sound was dependent on the magnitude of sound pressure (which is true for precavitational mode and mode poorly developed cavitation), dependence (34) can be written as [20]:

$$\alpha \approx \frac{1}{2\cdot(x_2-x_1)} \cdot \ln\left(\frac{P_1}{P_2}\right)^2 \quad (36)$$

where:

$$\alpha = \frac{1}{(x_2-x_1)} \cdot \ln\left(\frac{P_1}{P_2}\right). \quad (37)$$

Now you need to choose the method of application of the formula (37). The problem is by the intensity of ultrasonic vibrations I1 and I2 or amplitude of sound tyskuP1 and P2 in the respective points vymirivx1 and x2. The solution can be a wayapplication of acoustic method using hydrophones, which is one of the most promising configuration to measure cavitation field intensity and the cavitation process [18]. This method hydrophone output value generated voltage (charge), which is proportional to the sound pressure. Thisway set mutual correspondence between electrical voltage and sound pressure. Then, passing on the values of sound pressure (4) to the voltage at the terminals of hydrophones, you can get the following relationship:

$$\alpha = \frac{1}{(x_2 - x_1)} \cdot \ln\left(\frac{U_1}{U_2}\right) \qquad (38)$$

where U_1 and U_2 - the voltage at the terminals at points hydrophone measurements.

Thus, analyzing the spectral composition of the signal hydrophones can indirectly judge the intensity of cavitation processes. Geometric dimensions hydrophones are minimized, allowing you to reduce the degree of distortion of the sound field during use. The method allows us to investigate how the shape of the sound field, and to assess the intensity of cavitation processes.During the reception mode piezoelement on the covers of hydrophones there is a potential difference, whose value is proportional to the sound pressure. Calibration of hydrophones can be done by various methods, such as reciprocity standard method [9].Note that measure the voltage proportional to the sound pressure can be achieved in various ways, including: a peak voltmeter, voltmeter mean and rms voltmeter. This measurement of different ways lead to different results.

Based on the fact that the shape of the measured voltage differs significantly from harmonious, the measurement was performed rms voltmeter V3-57 values. In particular, used in measurements hydrophone sensitivity was M = 7,9 * 10 -5 B / Pa. This measured voltage is proportional to the pressure not only sound, but also the intensity of ultrasonic vibrations.

As a result of experiments and processing factors were identified fading fluctuations technological environments with different rheological properties, which calculated rates viscosity. In general, we note that the effect of viscosity is essential for small values of the amplitudes of the initial stage of the formation of bubbles, which have small radii. On the bubble with a large initial radius viscosity affects little. The reason is that in the initial stage of bubble short-range as a result of viscous forces are constrained in their rise. This conclusion is logical and to intensify the cavitation process for handling the application process by increasing the acoustic pressure. Such a result demonstrates that perhaps the formation of bubbles is somewhat spontaneous, momentary lack of bubbles and slamming requires AC amplitude-frequency range of the acoustic loading system.

The absorption coefficient depends on the frequency of ultrasonic waves, temperature and properties of the medium. The coefficient of viscosity for some fluids are given in Table 2.

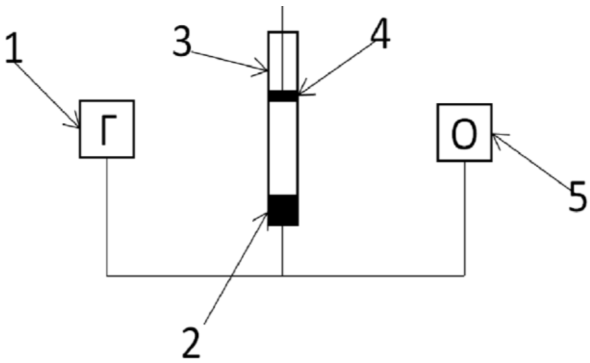
Therefore, the coefficient of viscosity is an important parameter that affects the formation of cavitation bubbles, their development and final stage of the production process – compression and collapse. It should be noted that the viscosity can influence the education and development of the form of the bladder, which is usually taken in the form of a sphere. Thus, the formation of the structure of the medium reaction on the fluctuations of the acoustic device needs to take into account the viscous properties of the medium.

One of the parameters, which depends on the influence of elastic-inertial characteristics of fluid flow cavitation process is the speed of wave propagation C0:

Methodology the chosen method of determining the velocity of waves shown in figure 7.

Table 2. Coefficients of viscosity

№, p/p	Name of the medium	Density, ρ kg/m^3	Coefficient of viscosity, $\mu \cdot 10^{-3}\,Па \cdot c$
1	water	1000	0,82
2	ethyl alcohol 96%	798	1,2
3	transformer oil	900	30
4	olive oil	950	85



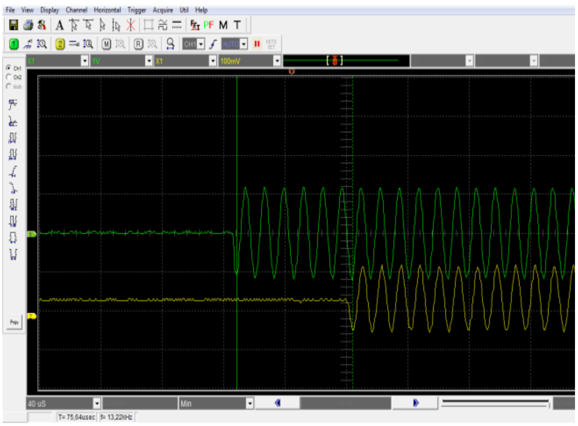
1 – pulse generator, 2 – emitter, 3 – tube with the process medium, 4 – reflector, 5 – computer

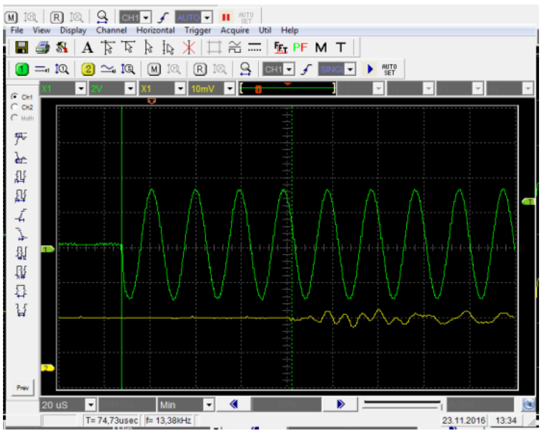
Fig. 7. Medium wave propagation in a technological environment

From pulse generator 1 to the radiator 2 refers to an electrical signal of a fixed ultrasonic frequency. The sensor, which in this case is emitter and receiver, converts the entered signal into elastic oscillations of the same frequency (inverse piezoelectric effect), which pass through the layer of the technological environment. The receiver converts the elastic vibrations of ultrasonic frequency into an electrical signal of the same frequency (direct piezoelectric effect) and sends a signal on the computer screen 5. On the computer screen reflected pulse generator and the signal passed through the tube with the technological environment. Distance between h describes the time t of passage of elastic waves from the source to the reflector and back. Consequently, the speed of wave propagation in a technological environment is determined by the formula:

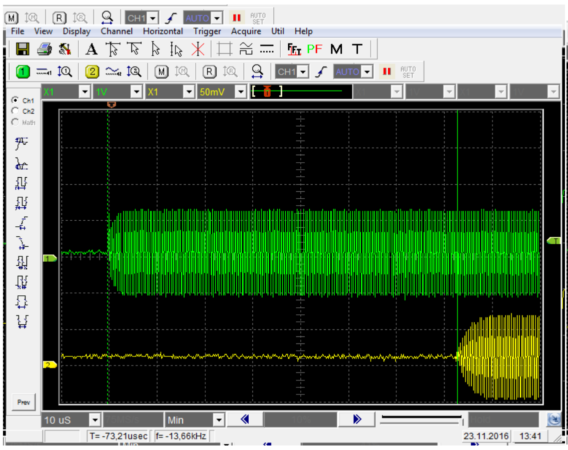
$$c = h / t \qquad (39)$$

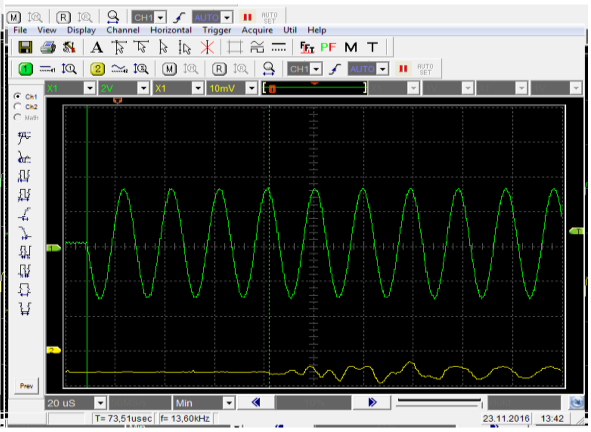
In Fig. 8 – given characteristic vprogram for measurements of acoustic parameters of different technological environments, the processing vincentelli wave propagation (tab. 3).



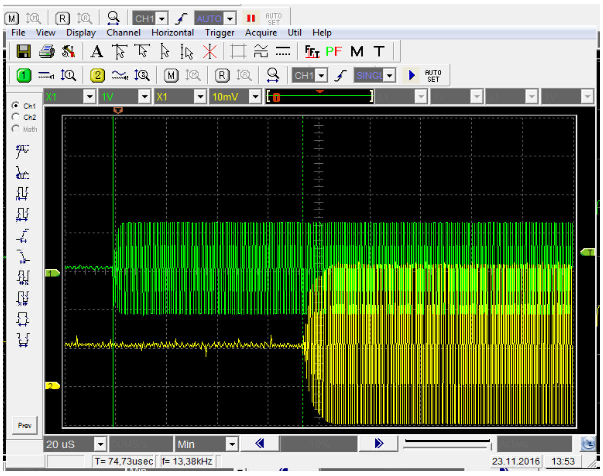


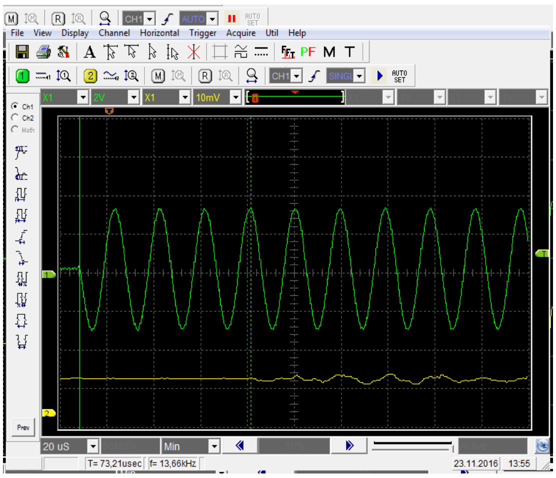
a *b*





c *d*





e *f*

water: f= 2.58 GHz and, f= 52 kHz –b, milk:f= 2.58 MHz V, f= 52 kHz –g, sunflower oil: f= 2.58 GHz –d, f= 52 kHz –E.

Fig. 8. Typical vprogram for measurements of acoustic parameters of technological environments

Table 3. The numerical values of the speed of technological environments

Environment	Speed of sound, m/s	Density, kg/m^3
Water	1484	1000
Sea water	1531	1030
Engine oil	1385	860
Olive oil	1381	950
Castor oil	1477	850
Diesel oil	1250	850
Epoxy resin	2580	1200
Glycerin	1923	1270
Kerosene	1324	800
Sulfuric acid	1440	1830
Mercury	1453	13600
Acetone	1174	810
Methanol	1103	792
Ethanol	985	798

CONCLUSIONS

1.The knowledge of coefficient of viscosity of technological environment is a necessary condition to determine the level of energy consumed for the components of the process of origin and development of cavitation. The viscosity affects the formation, development of forms bubbles during their collapse.

2. Analytical dependences allowed us to determine the viscous properties of the technological environment, which is modeled by a discrete or distributed parameters for custonline and customization laws of change of the dissipative characteristics of the technological environment in the process of its acoustic treatment.

3. The dependence of the sound absorption coefficient from the status parameters and frequency is the criterion for evaluating and bears full information on specific technology environment, the processes of acoustic treatment.

4. Experimental measurement of the speed of wave propagation in a technological environment is carried out by comparing the phases of two signals which are passed from the contact zone of the cavitator through the medium under test to a rigid boundary. The comparison of phases is made either into acoustic (transducer) or electrical (measuring receiver) paths.

5. Evaluation of elastic-inertial properties of the medium flow cavitation process due to the accurate knowledge of the speed of sound, the numerical values which are determined for a range of technological environments.

6. Change the speed of propagation of waves and the sharp drop in density leads to a significant reduction of wave resistance of the medium that is taken into account in the definition of parameters and regimes of the cavitation apparatus.

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Table of Contents