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ABSTRACT

On the dissertation for the degree of Doctor of Philosophy

VIBRATION-FREQUENCY DENSITY METER OF LIQUID BASED ON A SINGLE-TUBE RESONATOR OF INCREASED QUALİTY FACTOR

Specialty:	3337.01	Information - measurement and control systems (technological measurement)
Field of science:		technical sciences
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DISSERTATION CONTENT

Relevance of the topic. In some areas of industry, including oil industry, the requirements for extraction of petroleum products, delivering accounts, and measuring their quantity during transportation of oil through pipes have increased. At the same time, creation and application of new devices and equipment for accurate determination of density of petroleum products has made actual. The measurement of density during the transportation of petroleum products through the pipe in the stream, the automatic measurement of the fluid density in the continuous production mode is required with defining a very small error.

Applied density meters provide measurement with accuracy small errors in automated control systems of technological processes (CA TP), perform in the fields of complex conditions of operating conditions, in the environment of vibrations, temperature changes, viscosity of liquids, etc.

Flow density meters in liquid medium is considered as one of the main nodes during information-measurement exchange in systems of controlling automated of technological processes (CA TP) in food, chemical, petrochemical and other industries.

Vibration-frequency method has found wider application among density measurement methods in information-measurement systems by means of flow density meters. First of all, this is explained by the conversion of the density measurement directly into the frequency signal in the measurement converters of vibration-frequency density units (VFD).

In this regard, vibration-frequency densities are preferred over analog-to-Analog Devices compared to other types of liquid densities. The main parameter of the VFD, which determines the accuracy of measurement, is the quality of its sensitive element. Such as oscillating moving coil, coating, cover, membrane, pipe, etc.as sensitive element. mechanical resonators are used. These mechanical resonators form the operation of the mechanical oscillation system organized with distributed and centering parameters.

From this point of view, tubular resonators with distributed parameters have higher quality, which is why they are widely used. They divided into single-tube or double-tube resonators. Camerton resonator measuring density meters have higher quality than single-tube resonator density meters. The complexity of the production of the Camerton resonator density meters is that the manufacturers of the leading vibration-frequency density meters have switched to the production of single-beam resonator density meters, the preparation of which is more simple and convenient to use in series production.

At the same time, for the time being, the quality parameters of the used single-beam resonators are largely inferior to the single-beam resonators.

It should be noted that the expansion of the field of application of density meters in industry has led to a significant complication of their working conditions. First of all the significant expansion of the range of temperatures, pressures, the level of vibrations and a number of other influencing factors.

Requirements for density meters include highly contaminated liquids, as well as liquids with additional components (free water, mechanical inclusions, etc.).) have increased in terms of ability to work. In this area, Great Britain's Solarton, Japan's Yokogawa, etc., worldwide. Companies occupy one of the leading places. In Azerbaijan, the EIB density meter of Neftkimyaavtomat is widely used in MDB countries. Y.K.Taranenko, Y.P.Zhukov, V.V.Navrotsky, A.Q.Murashov, M.V., Kulakov M.V. Along with the research of such scientists as Kulakov, Azerbaijani scientists T.K.Huseynov and N.A.Abdulova's studies took place. Research in this area continues today.

In connection with the above, the search for scientifically substantiated principle of single-boron quality resonators of structure, shape and construction and the development of high-precision liquid density meters on their basis are actual scientific-technical and technological issues.

The aim of the dissertation: The purpose of the dissertation is devoted to the development and study of a single-tube resonator of vibration-frequency densities in a liquid medium in an information-measuring system of an automated control system of technological processes (CA TP).

Scientific novelty of the dissertation. In the course of the work, the following main conclusions that differ in scientific novelty are drawn to the defense:

1.synthesis of the form of a high-quality single-beam resonator using the method of electromechanical analogies.

2. development of a mathematical model of a single-layer resonator of a stepped-variable cross-section.

3.development of engineering methodology of calculation of single-layer resonator with given absolute precision and high quality step-variable cross-section.

4.principles of construction of StepWise-variable cross-section single-beam resonator, which provides lowering of the main destabilizing factors (temperature, pressure and flow rate of liquid measured density) that affect the accuracy of density measurement.

Research methods. The basis of the conducted researches is mathematical physics, theory of electromechanical analogies, theory of dances and theoretical bases of information-measurement techniques.

The reliability of the obtained results ensured by comparing the numerical results known in the literature in special cases with mathematical accuracy, analytical formulas obtained by strict analytical methods.

The practical significance of the dissertation. The engineering methodology of the calculation of the parameters of a single-beam resonator of a stepped variable cross-section allows to determine its geometric dimensions at the design stage, taking into account the reactive forces falling on the supports and the material of the resonator to ensure the high quality of the resonator and the condition of ensuring the given absolute sensitivity.

The device designed and designed to measure the quality of the mechanical oscillation system vibration-frequency densities and other mechanical vibration transmitters can be used for experimental research.

Realization of the results of the dissertation work. The dissertation work was carried out in the scientific research work of the problem Laboratory of the Department of “Electronics and automation” of Azerbaijan oil and Industry University. It was worked out directly in the developed theoretical and practical research work with the participation of the author:

-A new high-quality stepped variable-cross-section resonator has been developed for vibration-frequency density meters. The results of scientific researches were applied in laboratory and teaching-methodical works of Azerbaijan oil and Industry University (Baku City) and Sumgayit State University (Sumgayit City).

-The device measuring the quality of the mechanical dance system of the resonator of the vibration-frequency density meter based on the single-beam resonator has been applied at the objects of the scientific institution “Neftkimya avtomat” (Sumgayit city) and the oil and gas production department “Surakhani neft”.

- In addition, on the basis of the obtained results, patents of the Republic of Azerbaijan were obtained for the measurement of liquid medium density according to the results of research and application in various fields of industry (N98/001013,12.06.97, G01 N 9/04 and I 2008 0025, 28.01.2008 (Azerbaijan)).

The main theoretical and experimental studies submitted to the defense:

- mathematical model of one-bed resonator with the highest quality step-variable cross-section;

- minimization of reactive forces falling on the resonator's base and vibrational energy losses at the base of the housing unit;

- methodology for determining the rational parameters of the resonator at the design stage, while improving the quality and ensuring the absolute sensitivity as a result of minimization of vibrational energy in the resonator body joints;

- vibration-frequency development of single-section design of stepped-variable cross section for liquid density meter;

Approbation of dissertation work. The main results of the dissertation were reported, listened and discussed at the following conferences:

International scientific and technical conference "Measurement and control of granular materials (MCGM'97)", Shanghai, China X.R., 1997;

International scientific and technical conference "Machine Design and Production Conference (UMTIK'98) ", Ankara, Turkey, 1998;

International scientific and technical conference "Measurement and control of granular materials (MCGM'2000) ", Shanghai, China X.R., 2000;

International Conference "Problems of cybernetics and informatics "(Baku, Azerbaijan, 2008);

International scientific-practical conference "Scientific perspectives of the XXI century. Achievements and prospects of the new Century", Novosibirsk, Russia, 2014;

International scientific-practical conference "Modern concepts of scientific research", Moskva, Russia, 2014;

International scientific and technical conference "Applied science as a tool for the development of petrochemical industries ", Salavat, Russia, 2017;

International Scientific and Technical Conference: SES-2019, Kazan, Rusiya, 2019;

International scientific and technical conference ”Industrial engineering”, Russia, 2021;

III International conference MIP: engineering-2021: Advanced technologies in material science, mechanical and automation engineering, Krasnoyarsk ş., Russia, 2021;

as well as:

Theses of the Republican scientific-practical conference "Ecology and Progress", Sumgayit city, Azerbaijan, 1999;

Abstracts of the Republican scientific conference " Life protection", Sumgayit city, Azerbaijan, 1998;

Abstracts of the Republican scientific conference "Modern problems of informatization, cybernetics and information technologies",Azerbaijan, 2004;

Abstracts of the Republican scientific conference "Materials of IX and XI Republican scientific conference of graduate students and young researchers", Baku, Azerbaijan, 2003 and 2006 ;

Theses of the Republican scientific conference "Applied Problems of Mathematics and new information technologies", Sumgayit city, Azerbaijan, 2007;

Information systems and technologies: achievements and prospects. Materials of the international scientific conference, Sumgayit city, Azerbaijan, 2018 and 2020;

The structure and volume of the dissertation work. The dissertation consists of an introduction, four chapters, conclusion, list of literature and appendices. The work is presented on 175 pages, contains 50 pictures and 11 tables, and a list of 149 titles of literature.

The total volume of the dissertation with the sign. The total volume of the dissertation consists of 162 644 characters. In the introduction to the dissertation there are 12881 signs, in the 1st chapter 46434 signs, in the 2nd chapter 20969 signs, in the 3rd chapter 20287 signs, in the 4th chapter 53214 signs.

Publications on the dissertation: 14 articles, 20 theses and 2 patents (inventions) on the topic of the dissertation were published.

In the introduction, the relevance of the research work is substantiated, the purpose of the work is formulated, as well as the main scientific results of the dissertation are listed, the application areas of the research results are indicated and their practical significance, as well as the main provisions submitted for defense are given.

In the first chapter deals with the main requirements placed on modern liquid flow densities measuring density automatically are formulated, and the prospects of vibration-frequency densities that provide these needs are substantiated. As a result, as a result of the analysis of the state of vibration Densitometers, closed-type aerated resonator Densitometers have the best characteristics, but their inadmissibility in series production in practice requires replacing them with lower-quality simple single-beam resonators. In this regard, the search for vibration density meters on the basis of high-quality single-layer resonators of new shape and construction is an actual issue.

The second chapter is devoted to the study and development of mathematical model of single-beam resonator with variable-beam cross-section. Analyzes carried out in the field of development of vibration-frequency liquid density meters show that at present, two methods of synthesis of tubular resonators can be distinguished: heuristic synthesis and synthesis using the method of electromechanical analogies. The possibilities of scientific justification of the synthesis of the shape of the resonator show that it is more expedient to conduct a synthesis by the method of electromechanical analogies. According to this method, the synthesis of the algorithm is as follows:

1. selection of a resonator based on this method during the synthesis of a new form ;
2. development of a linear model of the selected resonator with the collected parameters;
3. development of an electrical analog of a mechanical model of a resonator;
4. analysis of the electric analog and its improvement in order to minimize the amount of oscillatory energy of the electric analog;
5. development of a linear mechanical model of a high-quality resonator according to the analog improvement scheme;
6. presentation of its new form according to the linear mechanical model of the resonator.

In order to synthesize a new form of resonator according to the given algorithm, a single-tube is taken and a straight pipe 1 is prepared (Figure 1), the ends of the pipe are fastened to the supports 2.

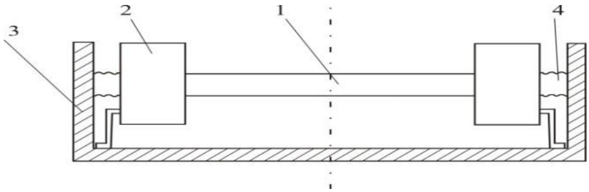


Figure 1. The initial form of the synthesized resonator

The resonator is connected with the 4 body through the 3 flexible elements, through which the inclusion and outflow of fluid is performed, and the registration of its state is carried out with the 5 sensitive plate.

Taking into account the fact that the resonator forms a double symmetry with respect to the center, we make a mechanical model for the same half, taking one side from its half (Figure 2). Let's name the mass of the moving half of the pipe m_1 , the mass of the support m_2, and the mass of the base M . Masses are under elastic-plate interaction between themselves. In the given model, these interactions are replaced by mechanical resistances r_1 and r_2 containing c_1 and c_2 flexible elements.

According to the method of electromechanical analogies, the electrical analogue of the model (Figure 2) is a contour system, which is shown in Figure 3.

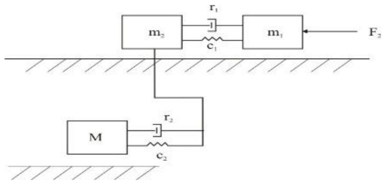


Figure 2. Mechanical model of the primary synthesized resonator with the collected parameters

Mechanical power is replaced by an equivalent voltage source in an electrical analogue.

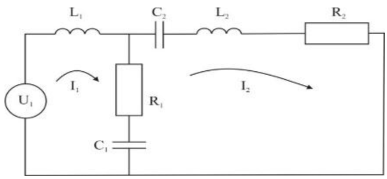


Figure 3. Electrical analogues of mechanical models with the accumulated parameters of the primary synthesized resonator

L_M Inductance can not be ignored, since the mass of the base is much larger than the M mass of the pipe and the stop. Currently, the losses in the supports correspond to the loss of energy in their R_2 resistance, which is proportional to the I_2 current passing through the R_2 resistance. Using the method of contours currents, let's adopt the next following marking for this:

$$z_{11} = j\omega l_1 + \frac{1}{j\omega c_1} + R_1, \qquad z_{12} = \frac{1}{j\omega c_1} + R_1$$

$$z_{21} = z_{12}, \quad z_{22} = \frac{1}{j\omega c_1} + R_1 + j\omega l_2 + \frac{1}{j\omega c_2} + R_2$$

The system of equations is as follows for the current values of the current:

$$\begin{cases} I_1 z_{11} - I_2 Z_{12} = U \\ -I_1 z_{12} + I_2 Z_{22} = 0 \end{cases} \tag{1}$$

Then the price of the I_2 current:

$$\Delta z = \begin{vmatrix} z_{11} - z_{12} \\ - z_{12} z_{22} \end{vmatrix}; \tag{2}$$

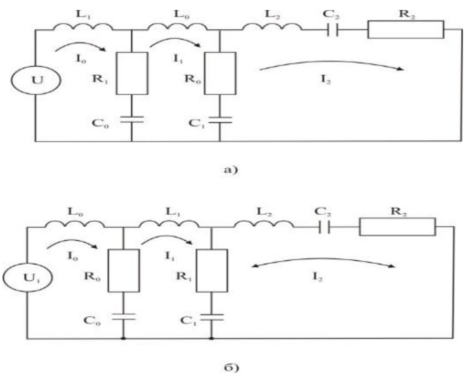
$$I_2 = \frac{1}{\Delta z} = \begin{vmatrix} z_{11}U \\ -z_{12}0 \end{vmatrix} = \frac{Uz_{12}}{z_{11}z_{22} - z_{12}^2}; \qquad (3)$$

$$z_{11}z_{22} - z_{12}^2 \neq 0$$

From the expression (3) we conclude that if the number of I_2 current is small, then the denominator of the (3) fraction will be large. His is the most rational way to reduce its I_2 current increase of z_{22} resistance, so to be more precise l_2 increase, because R_1 and C_1 corresponds to the parameters of the tube called resonator. So these parameters are selected at the end of the measurement conditions and the given sensitivity can not be changed.

R_2 the increase in energy leads to an increase in the loss of energy in the supports, and C_2 the decrease in it corresponds to a decrease in the rigidity of the connecting elements, which are selected for constructive considerations.

I_2 there is another way to reduce its current, which is the inclusion of an $L_0 - R_0 - C_0$ additional circuit in the scheme. In this case, two options for inserting an additional circuit are possible: in front $L_1 - R_1 - C_1$ (figure 4a) or $L_1 - R_1 - C_1$ and $L_2 - R_2 - C_2$ (figure 4b). We study each variant separately.



Picture 4. Electrical analogues of mechanical models with accumulated parameters of improved shaped resonators

Variant I. Let's accept the following naming as in the previous case :

$$z_{00}^{*}=j\omega l_0+\frac{1}{j\omega c_0}+R_0,\quad z_{01}^{*}=R_0+\frac{1}{j\omega c_0}$$

$$z_{10}^{*}=z_{01},\qquad z_{11}^{*}=R_0+\frac{1}{j\omega c_0}+L_1+R_1+\frac{1}{j\omega c_1}$$

$$z_{12}^{*}=R_2+\frac{1}{j\omega c_2},\quad z_{21}^{*}=z_{12}^{*}$$

$$z_{22}^{*}=R_2+\frac{1}{j\omega c_1}+L_2+R_3\frac{1}{j\omega c_2}$$

We compile a system of equations for current values:

$$\begin{cases} I_0z_{00}^{*}-I_1z_{01}^{*}=U \\ -I_0z_{01}^{*}+I_1z_{11}^{*}-I_2z_{12}^{*}=0 \\ -I_1z_{12}^{*}+I_2z_{22}^{*}=0 \end{cases} \tag{4}$$

Then I_2 the price of the current :

$$\Delta z=\begin{vmatrix} z_{00}^{*} & -z_{01}^{*} & 0 \\ -z_{01}^{*} & z_{11}^{*} & z_{12}^{*} \\ 0 & -z_{12}^{*} & z_{22}^{*} \end{vmatrix}; \tag{5}$$

$$I_2=\frac{1}{\Delta z}=\begin{vmatrix} z_{00}^{*} & -z_{01}^{*} & U \\ -z_{01}^{*} & z_{11}^{*} & 0 \\ 0 & -z_{12}^{*} & 0 \end{vmatrix}=\frac{Uz_{01}^{*}z_{12}^{*}}{z_{00}^{*}(z_{11}^{*}z_{22}^{*}-z_{12}^{*2})-z_{01}^{*2}z_{22}^{*}} \tag{6}$$

Comparing the schemes in Figure 3 and 4 among themselves, we see that,

$$z_{11} = z_{11}^* - z_{01}^*$$
$$z_{12}^* = z_{12}$$
$$z_{22}^* = z_{22}$$

If we describe in it the expressions (3) and (6) in the following form:

$$I_2 = \frac{Uz_{01}^* z_{12}^*}{z_{00}^*(z_{11}^* z_{22}^* - z_{12}^{*2}) - z_{01}^{*2} z_{22}^*},$$
$$I_2 = \frac{Uz_{12}}{z_{11}^* z_{22} - z_{01}^* z_{22} - z_{12}^2}$$

By z_{01} multiplying the copy and denominator of the second fraction I_2 / I_2^* we find the connection:

$$\frac{I_2}{I_2^*} = \frac{z_{00}^*\left(z_{11}^* z_{22} - z_{12}^2\right) - z_{01}^{*2} z_{22}}{z_{01}^*\left(z_{11}^* z_{22} - z_{12}^2\right) - z_{01}^{*2} z_{22}} \qquad (7)$$

So, if it is $z_{00} > z_{01}$, then $I_2 / I_2^* > 1$, and I_2 the second is less than the first.

Varinat II. By conducting an analog conversion, we get :

$$\frac{I_2}{I_2^*} = \frac{z_{22}^*\left(z_{00}^* z_{11}^* - z_{10}^{*2}\right) - z_{00}^* z_{12}^*}{z_{12}^*\left(z_{00}^* z_{22}^* - z_{10}^{*2}\right) - z_{00}^* z_{12}^* + z_{00}^* z_{12}^* z_{12}} \qquad (8)$$

(8) as it appears from the expression that, z_{11} by way of selecting the parameter $I_2 / I_2^* > 1$ the fulfillment of his condition can be achieved.

We draw up the model according to the distributed parameters of the resonator in relation to the scheme in Figure 4 as in Figure 5.

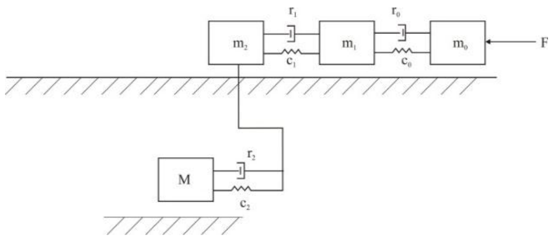


Figure 5. Mechanical model with aggregated parameters of improved shaped resonator

The model given in a simple case is suitable for the implementation of resonator with step-shifting cross section, pipe ends in a solid joint form (Figure 6). The found form of the resonator provides for the reduction of the reactive force formed in the places of attachment to the supports during its oscillation, which, in comparison with the previous form of the resonator, ultimately provides for its quality improvement.

For the methodology of conducting the resonator report, its exact mathematical model is developed and studied.

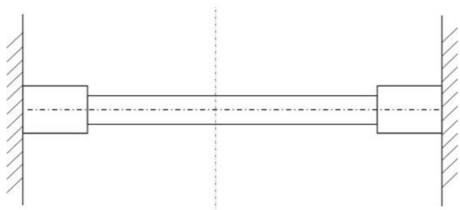


Figure 6. New synthesized resonator shape

For this purpose, the structural model of the resonator has been studied, the general view of this resonator is shown in Figure 7.Resonator stage-consists of variable cross-section 1 pipe, the ends of which are firmly fixed on 2 supports. The operating mode of the resonator is created by an alarm system in the first harmony of the pipe in motion. The alarm system consists of 3 electromagnetic receivers and 5 electronic amplifiers with 4 oscillators connected to the corresponding input and output. The frequency of the authorization changes with a change in the density of the fluid passing through the tube and is taken from the outlet of the amplifier.

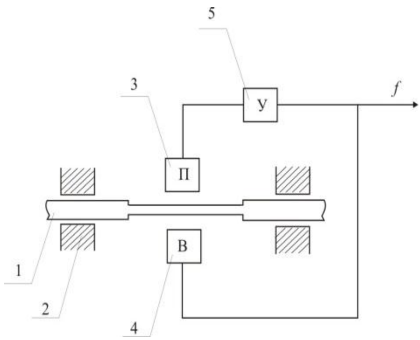


Figure 7. General view of resonator

The task consists in determining the analytical dependence of the resonator between the specific frequency of oscillations and the density of the fluid contained in the resonator.

Given the absolute symmetry of the resonator, the report scheme can be adopted as in Figure 8, i.e., we can look at the implementation of the task for the half-section of the pipe.

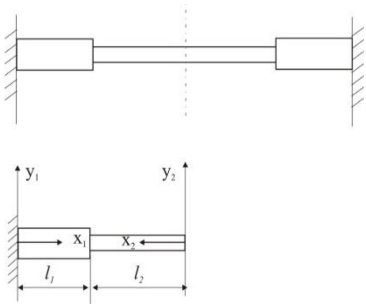


Figure 8. Reporting scheme of the resonator

Conditionally divide the half of the pipe into two areas : the first – the area from the pipe joints to the supports to the change of its outer diameter; the second – the area from the area where the outer diameter changes to the middle of the pipe. If we take the lengths of these accepted areas of the pipe, respectively, l_1 and l_2, on it $l_1 + l_2 = l$. Other parameters of the pipe are as shown in the scheme. We build two coordinate systems that are connected in each field. Let's name the inclination of the axis of the pipe in each area accordingly y_1 and y_2. These quantities are states of points on the pipe, determined by t time function x_1 and x_2 coordinates. If we do not take into account friction, the motion equation will take the following picture:

$$\begin{cases} EJ_1 \dfrac{\partial^4 y_1}{\partial x_1^4} + m_1 \dfrac{\partial^2 y_1}{\partial t^2} = 0; \\ EJ_2 \dfrac{\partial^4 y_2}{\partial x_2^4} + m_2 \dfrac{\partial^2 y_2}{\partial t^2} = 0; \end{cases} \tag{9}$$

here – E modulus of elasticity; – J_1, J_2 moments of inertia by arrows of the cross-section of the pipe; m_1, m_2 - unit of mass of the length of the pipe filled with liquid.

A to conduct analysis we use Krylov functions and integrals. The boundary conditions for the case under consideration will be as follows:

$$x_1 = 0; \quad y_1 = 0; \qquad \frac{\partial y_1}{\partial x_1} = 0;$$

$$x_2 = 0; \quad \frac{\partial y_2}{\partial x_2} = 0; \quad \frac{\partial^3 y_2}{\partial x_2^3} = 0;$$

On the condition of connection $x_1 = l_1$ və $x_2 = l_2$ when the writings are as follows:

$$y_1 = y_2; \qquad \frac{\partial y_1}{\partial x_1} = -\frac{\partial y_2}{\partial x_2};$$

$$EJ_1 \frac{\partial^2 y}{\partial x_1^2} = EJ_2 \frac{\partial^2 y_2}{\partial x_2^2}; \qquad EJ_1 \frac{\partial^3 y_1}{\partial x_1^3} = -EJ_2 \frac{\partial^3 y_2}{\partial x_2^2} \tag{10}$$

If we conduct substitution as follows:

$$y_i(x_i, t) = z_i(x_i)v(t), \quad i = 1,2 \tag{11}$$

Where $z_i(x_i)$ solution of differential equation from IV degree :

$$z_i^{IV} - v_i^4 z_i = 0; \tag{12}$$

it is possible here, $v(t)$ – the solution of the differential equation from the 2nd degree :

$$v_i + \omega \upsilon_i = 0;$$

$$\omega = v_i^2 \sqrt{\frac{EJ_i}{m_i}} \tag{13}$$

Here $\omega = 2\pi f$ the frequency of the cycle of the dance and f - this is the specific frequency of the dance. Below we proceed from (9) and (10) equations to ordinary derivative equations.

$$\begin{cases} z_1^{IV} + v_1^4 z_1 = 0; \\ z_2^{IV} + v_2^4 z_2 = 0; \end{cases} \tag{14}$$

when there are the following boundary conditions:

$$z_1(0) = 0; \qquad z_1^{'}(0) = 0; \qquad z_2^{''}(0) = 0; \qquad z_2^{'''}(0) = 0;$$

$$z_1(l_1) = z_2(l_2), \qquad z_1^{'}(l_1) = -z_2^{'}(l_2),$$

$$z_1^{''}(l_1) = \frac{E_2 J_2}{E_1 J_1} z_2^{''}(l_2), \qquad z_1^{'''}(l_1) = -\frac{E_2 J_2}{E_1 J_1} z_2^{'''}(l_2), \quad z_1^{''''}(l_1) = -\frac{E_2 J_2}{E_1 J_1} z_2^{''''}(l_2) \tag{15}$$

$$haradaki, \quad v_i^4 = \frac{m_1 \omega^2}{E_i I_i}, \; i = 1,2$$

In order to simplify writing, Let's adopt the following naming:

$$U_i = U(l_i \nu_i); \quad S_i = S(l_i \nu_i);$$

$$T_i = T(l_i \nu_i); \quad V_i = V(l_i \nu_i);$$

To solve the equation (15), taking into account the first four conditions described in the expressions in the Krylov function (13), it can be written as follows :

$$\begin{cases} z_1(x_1) = a_1 U_1 + b_1 V_1; \\ z_2(x_2) = a_2 U_2 + b_2 S_2; \end{cases}$$

(16)

where, a_1, a_2 and b_1, b_2 – desired constants. Using the terms of connection, we get 5-8 conditions of the system (15):

$$\begin{cases} a_1 U_1 + b_1 V_1 = a_2 U_2 + b_2 S_2; \\ a_1 T_1 + b_1 U_1 = k_1 a_2 T_2 + k_1 b_2 V_2; \\ a_1 S_1 + b_1 T_1 = k_2 a_2 S_2 + k_2 b_2 U_2; \\ a_1 V_1 + b_1 S_1 = k_3 a_2 V_2 + k_3 b_2 T_2; \end{cases} \quad (17)$$

where is that,

$$k_1 = -\sqrt[4]{\frac{E_1 J_1 m_2}{E_2 J_2 m_1}}; \; k_2 = \frac{E_2 J_2}{E_1 J_1} k_1^2; \; k_3 = \frac{E_2 J_2}{E_1 J_1} k_1^3;$$

Let's compose a matrix.

$$V = \begin{vmatrix} U_1 V_1 \\ T_1 U_1 \end{vmatrix}; \quad \Phi = \begin{vmatrix} U_2 S_2 \\ k T_2 k V_2 \end{vmatrix};$$

$$V_1 = \begin{vmatrix} S_1 T_1 \\ V_1 S_1 \end{vmatrix}; \quad \Phi_1 = \begin{vmatrix} k_2 S_2 k_2 U_2 \\ k_3 V_2 k_3 T_2 \end{vmatrix}; \quad (18)$$

$$F_1 = \begin{vmatrix} a_1 \\ b_1 \end{vmatrix}; \qquad F_2 = \begin{vmatrix} a_2 \\ b_2 \end{vmatrix};$$

On it (17) equation can be written as follows:

$$\begin{cases} F_1 V = F_2 \Phi \\ F_1 V = F_2 \Phi_1 \end{cases} \quad (19)$$

or

$$XF_1 = 0 \qquad (20)$$

where $X = (\Phi_1 \Phi^{-1} V - V_1) F_1 = 0$, on it, its elements are designated as:

$$x_{11} = k_1 k_2 U_1 (S_2 V_2 - U_2 T_2) + k_2 T_1 (U_2^2 - S_2^2) - k_1 S_1 (U_2 V_2 - T_2 S_2);$$
$$x_{12} = k_1 k_2 V_1 (S_2 V_2 - U_2 T_2) + k_2 U_1 (U_2^2 - S_2^2) - k_1 T_1 (U_2 V_2 - T_2 S_2);$$
$$x_{21} = k_1 k_3 U_1 (V_2^2 - T_2^2) + k_3 T_1 (T_2 U_2 - S_2 V_2) - k_1 V_1 (U_2 V_2 - T_2 S_2);$$
$$x_{22} = k_1 k_3 V_1 (V_2^2 - T_2^2) + k_3 U_1 (T_2 U_2 - S_2 V_2) - k_1 S_1 (U_2 V_2 - T_2 S_2);$$

(19) it is necessary to comply with the condition of the formula for the presence of a solution that differs from zero $\det x = 0$. Opening the identifier, we get the equations for determining the frequencies of the specific oscillations of the analyzed resonator tube:

$$x_{11} x_{22} - x_{21} x_{12} = 0$$
(21)

Let us proceed to the second part of the issue, i.e., to the question of finding the analytical dependence between the parameters of the resonator and the number of reactive force in the places of conjugation of the resonator.

In accordance with the theoretical part, the force in the compound power is determined as follows:

$$F = EJ_1 y_1 (0,t)$$

This is also the harmonic function of the time, the function is $v(t)$ such function. The amplitude price of this quantity is equal to the following:

$$F_A = EJ_1 u_1 (0)$$

(16) considering the expression

$$u_1(x_1) = (U(v_1 l_1) V(v_1 l_1)) F_1 \qquad (22)$$

where

$$u_1(0) = v_1(0,1) F_1$$

(20) with respect to the testimony F_1 – this is v_1 a special vector of the X matrix calculated at the time v_1 of its prices.

Which according to the thesis is determined with accuracy up to the speed of the scalar (21), which is the solution of the equation and can be as follows, for example, to be accepted:

$$F_1 = \frac{\lambda}{2EJ_1}\begin{pmatrix} x_{12} \\ -x_{11} \end{pmatrix} \tag{23}$$

F_1 we get the following statement by implying the description of the above :

$$F_A = \frac{\lambda}{2} v_1^3 x_{11}; \tag{24}$$

where λ - constant, which determines the intensity of the dances, which depends on the initial conditions.

As a sliding of the middle point of the pipe as a characteristic of the intensity of the oscillations h amplitude is acceptable. Let's assume that in the system, regardless of the parameters of the system h recording amplitude is provided. Let's express the amplitude through these parameters.

As long as,

$$h = z_2(0)$$

than

$$h = (0,1)F_2$$

(19) is taken from the expression $F_2 = \Phi^{-1} F_1 V$ (25)

(25) by opening the phrase and The found value (24) if we put it in place in the testimony λ buy for

$$\lambda = \frac{hE_2 J_2 k_1 (U_2 V_2 - S_2 T_2)}{U_2 (T_1 x_{12} - U_1 x_{11}) - k_1 T_2 (U_1 x_{12} - V_1 x_{11})}$$

(25) as follows from the statement that F_A when the following equation is performed, it is theoretically taken equal to zero:

$$U_2V_2 - S_2T_2 = 0 \tag{26}$$

In this case, by selecting the resonator parameters from the condition of the Equality (26), it is possible to achieve a sufficient reduction in the energy losses of the oscillations of the pipe from the support to the body by reducing the reactive forces in the places of connection of the pipe to the supports.

Using the obtained equal (26), in practice, a methodology has been developed for the calculation of parameters of single-row step-variable cross-section resonator. This method allows to realize in practice the calculation of parameters of variable cross-section single-section resonator with maximum absolute sensitivity to the density of the measured fluid and at the places of attachment of the resonator with maximum quality at the expense of minimization of reactive forces.

Let's look at ensuring the condition of maximum improvement of quality of single-beam resonator.

Let's accept the change in the opener so that there is convenience in the next reports

$$\omega_1 = \nu_1 l_1 = \sqrt[4]{\frac{m_1}{EJ_1}} \cdot \sqrt{6{,}28F_0} \cdot l_1 \tag{27}$$

$$\omega_2 = \nu_2 l_2 = \sqrt[4]{\frac{m_2}{EJ_2}} \cdot \sqrt{6{,}28F_0} \cdot l_2 \tag{28}$$

ω_1 suppose that, (21) it is the root of the equation and $\omega_1 = 3.155$. This time ω_2 (26) the root of the equation should be and $\omega_2 = 2.365$. This time(27) and (28) after the non-existent transformations in his statements, he takes the following form:

$$3.155 = 4 \cdot \sqrt[4]{\frac{(D_1^2 - d^2)\rho_T + d^2\rho_{жc}}{E(D_1^4 - d^4)}} \cdot \sqrt{6{,}28F_0} \cdot l_1 \tag{29}$$

$$2.365 = 4 \cdot \sqrt[4]{\frac{(D_2^2 - d^2)\rho_T + d^2\rho_{жc}}{E(D_2^2 - d^4)}} \cdot \sqrt{6{,}28F_0} \cdot l_2 \tag{30}$$

Taking into account the experience of the development of vibration-frequency Densitometers and the obtained expressions, the sequence of rational parameters selection of a single-boron step-variable cross-section resonator can be proposed as follows:

- ρ_T density and E selection of the material of the resonator taking into account the modulus of elasticity and the properties of the measured liquid;
- of the pipe arising from the technological condition of the measurement d determination of internal diameter;
- the outer part of the central part of the single-boron resonator D_1 diameter and D_2 selection of peripheral parts taking into account the technological condition of pipe preparation;
- arising from the experience of the development of vibration-frequency density meters, F_0 finding the specific frequency of the empty single-chamber resonator ;
- (30) by using the expression resonator l_2 reporting of the length of the periphery area;
- $\omega_1 = 3.155$ when (23) by using the expression resonator l_1 reporting the length of the center area;

Chapter III is devoted to the influence of the main destabilizing factors on the indicators of the measured medium vibration density transmitter, namely the influence of temperature, pressure and flow rate of the measured liquid.

As a result of the conducted studies, the following attitudes are taken to determine the change in the oscillations of the resonator:

- resonator temperature from t_0 to t during the change:

$$\Delta f_t = f_t - f_{to} = -\frac{1}{2} f_{t_0} \frac{A(\alpha_E - \alpha_L) + \rho(\alpha_E + 2\alpha_L)}{A + \rho} \Delta t$$

Where: α_E and α_L **- t**he temperature coefficient of elasticity and the coefficient of linear expansion, respectively; f_{t_0} – filled with liquid ρ_H density t_0 the frequency of oscillations of the resonator in temperature; f_t - filled with liquid ρ_H

density t the frequency of oscillations of the resonator in temperature;

- Ölçülən mayenin təzyiqinin P_0 -dan P -yə dəyişməsi zamanı aşağıdakı kimi təyin oluna bilər:

$$\Delta f_P = f_p - f_{po} = \frac{1}{2} f_{P_0} \frac{(VL)^2 S}{0.484 E(n^4 - 1)d^4} \Delta P,$$

where:

f_p - frequency of oscillations of the tube filled with liquid ,

P - pressure and ρ the density is denoted by;

f_{P_0} - frequency of oscillations of the tube filled with liquid;

ρ - density and $P_0 (0.1 мПА)$ starting pressure;

V – it is the coefficient of its brought length, which depends on the conditions of connection of the ends of the pipe.

v - during the change of measured fluid velocity

$$f = \frac{0.907d}{\ell^2} \sqrt{\frac{E}{\rho_T}(n^2 + 1)} \sqrt{\frac{A}{A + \rho}} \sqrt{1 - 0.405 \frac{\ell^2 \rho \upsilon^2}{Ed^2(n^4 - 1)}}.$$

Using differential circuits connected to the resonator and at the expense of the inclusion of compensators, a new construction of single-section stepped-variable cross-section is considered, ensuring the reduction of the effects of the above factors.

Analysis of the measurement error arising from the phase shift in the authorization system is carried out.

In the Chapter IV the results obtained as a result of experimental study of high quality single-beam resonator, the design of which was developed on the basis of the methodology given in chapter 2 of the dissertation are given.

To conduct experimental research, an installation was developed: this installation includes a signal generator of the Г3 112 type on the resonator and test board under study, a chronometer-density meter of the Ч3-34А type, a universal digital voltmeter of the В7-16А type, an amplifier of the 100У-101 type, a power source, an oscilloscope of the В7-16А type, an exciter and a transmitter.

Electromagnetic converters are used to record excitation and oscillations. In the receiver for adjusting the oscillation system to the resonant frequency EMP determined by the indirect method by its quantity, it is carried out through the resonant frequency of the resonator during the forced oscillations of its arms.

A special device has been developed to measure the quality of the resonator. The scheme of vibration-frequency densities on the basis of a single-boron step-variable cross-section resonator has been proposed.

The specific frequency and quality of resonator dances were investigated by experiment. The first experiment consists of two stages. At the first stage, the frequency of the oscillations of the resonator while it was idle, and at the second stage, the frequency of the resonator in its state filled with distilled water was measured.

The results of the experiment showed that the error of determining the frequency of specific oscillations of the step - variable cross-section resonator using the proposed analytical expressions did not exceed 10 percent.

During the second experiment, two resonators were investigated. The first is one-sided (top is smooth), in the second case, the stepped-variable cross-section. As a result, the experiment showed that the quality of the step-variable cross-section resonator was 2.33 times higher than the quality of the single-sided, i.e. smooth top resonator.

The practice of manufacturing vibration-frequency liquid density meters shows the need to automate the process of adjusting the electromagnetic impact system. When the electromagnetic receiver of the oscillations is in a motionless state, the movement of the electromagnetic amplifier of the oscillations to the left or to the right is continued until the maximum possible signal is generated at the output of the receiver.

The solution to the problem of automating the construction of the electromagnetic impact system of the resonator of vibration-frequency fluid density meters using the provisions of the theory of fuzzy regulation seems relevant.

As a controlled quantity, the action of the actuator receiver of the oscillations was considered. Figure 10 presents a simplified structural scheme of the system for automatic regulation of the displacement of the electromagnetic impact of the vibration-frequency liquid densitometer.

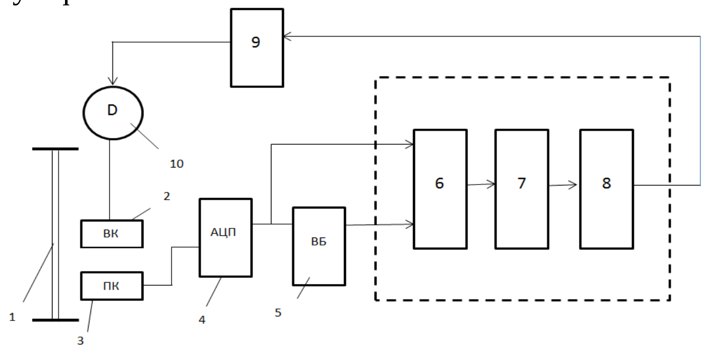


Figure 10. Simplified structural scheme of the system of automatic regulation of the electromagnetic activator of the vibration-frequency liquid density meter

To the input of the system, the voltage U from the 1 - block enters from the 4 - analog digit converter. The received price is given to one of the inputs of the fuzzy controller.

The received price is given to one of the inputs of the fuzzy controller. The second input includes derivatives dU/dt from the 5 calculation block.

Fuzzy controllers include: fazzifier-6, intended for the conversion of fuzzy signals into fuzzy sets, a set of fuzzy rules describing the fuzzy connections between the input and output parameters of the controller, i.e. a table of linguistic rules – 7; defazzifier - 8, where a fuzzy price obtained after defazzification in the form of a fuzzy control effect enters the input of the engine - 9 and Engine – 10. The following linguistic variables were used to work with fuzzy controllers:

1. Voltage. The voltage of the amplitude level of the oscillations.
2. Dynamics. Dynamics of voltage change(derivative of voltage).

3. Direction. Direction of the next switch of the engine.
4. Duration. The duration of the start of the electric motor.

Computational experiments are carried out using the Fuzzy Logic Toolbox software complex in the Matlab environment. The surfaces of the change of the direction of the next conduction in the process of the studied model and the duration of the electric motor connection time have been obtained. Figure 11 shows the surfaces of the change in the direction of the next passage of the electric motor and the connection time of the electric motor depending on the frequency of voltage oscillations and the price of its derivative.

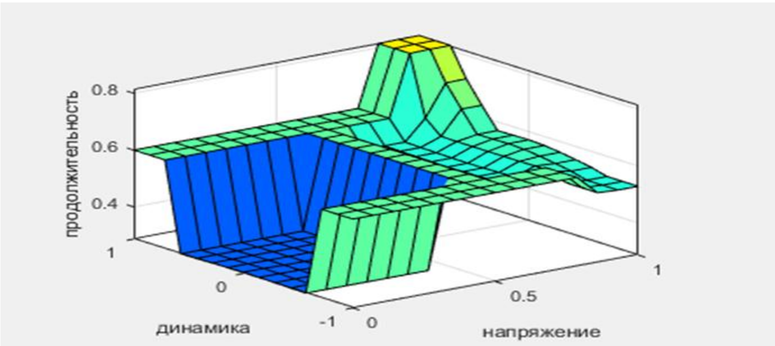


Figure 11. Surface dependence of output parameters of input variables

As a result of the analysis of the results obtained, it was established that the fuzzy controller in most cases performs a smaller amount of transitions than manual, and also allows maintaining the gap between the tube and the receiver of oscillations.

This reduces the time for adjusting the level of the resonator oscillation frequency and does not require increasing the requirements for the accuracy of the geometric dimensions of the pipe. It should also be noted that devices based on fuzzy logic have another important feature of relatively simple expansion.

It is easy to add new features and functional capabilities to such devices, it is not complicated. That is, if there is a need to include additional functions, there is an opportunity to add them to the operation of the fuzzy device. For this reason, devices based on fuzzy logic are relatively easy to use compared to others and can be reprogrammed with new features just in case of current need.

The procedure for adding new functional capabilities is simple and not complicated. Therefore, adding new features when the need arises does not create complexity. As a result of the studies, a number of results were obtained:

1. Fuzzy controls were adopted in most cases, so that the realization of less transitions was achieved in comparison with the presence of manual switches. This density leads to a decrease in time for adjusting the amplitude level of the oscillations of the meter.

2. Devices based on fuzzy logic have one more important feature - simple expansion, which is relatively comparable. It is easy and not complicated to add new features, new features for such devices. That is, if additional functions are required, it is possible to add them to the fuzzy device.

It is confirmed that devices based on fuzzy logic are more preferable for automatic adjustment of the level of amplitude of oscillations of vibration-frequency densities than devices based on ordinary logic. Automatic adjustment of the level of the amplitude of the oscillations becomes more qualitative, the number of transitions decreases.

A qualitatively new direction is the creation and development of transmitters with the transformation of directly controlled parameters into frequency - modulating signals-in the direction of creating high-precision and reliable density meters used in various fields of industry. The single-beam resonator, which differs from other high-quality structures with a stepped cross-section, allows to expand the application areas of vibration-frequency densities.

In particular, the concentration of disperse systems of suspensions and pipelines, which are the raw materials or products of a large number of technological processes in various sectors of the industry, increasing the accuracy of measurements when measuring the density by vibration-frequency Densitometers can significantly increase the importance of using these resonators.

En-section step-shifting resonators can be successfully used in vibration amplitude density meters, where single-section resonators are traditionally used.

The principle of operation of these devices is based on the dependence of the amplitude of forced oscillations of the tubular resonator on the density of the fluid passing through it. At the same time, the greatest sensitivity of the device is provided during its operation in the immediate vicinity near the resonance area.

Initially, the resonator is filled with liquid taken as a sample, for example, with distilled water, then its oscillation is tuned to the system resonance state, but at the same time it registers the maximum price of the amplitude of the oscillations.

In addition, the resonator is filled with the studied liquid, for example, it is filled with a water-cement mixture that differs from the comparable density. The resonance condition is disrupted and the amplitude of their oscillations decreases. The measurement limit is changed by selecting the comparable fluid and tuning it to the subsequent resonance state.

The effect of the amplitude of the oscillations and the measurement of the amplitude of the oscillations are carried out by changing current electromagnets as a rule. Vibration-amplitude as a sensitive element of the density meters, straight tubes firmly fixed at the ends are used.

Due to the large scattering energy in the places of connection of the resonator tube to the supports, other structures receive a small quality, which sharply limits the amount of possible amplitude of the oscillations in such mechanical oscillations, and therefore the potential measurement sensitivity is also reduced.

Therefore, improving the quality of vibration-amplitude densities by preparing and using a cross-section step-by-step variable for a single resonator can increase the measurement precision and accuracy of these devices.

It should be noted that one-way variable resonator can be regarded as a special case of one-way resonators with variable stiffness. Therefore, further research in this area may be related to the search for new forms of monorail resonators of high quality with variable hardness.

One of the promising directions of possible application of single-beam resonators of stepped-variable cross-section is the possibility of constructing vibration-frequency densities for suspensions on their basis.

A characteristic parameter in the construction of vibration-frequency densities for suspensions on the basis of a single-boron resonator with a stepped variable cross-section is the concentration(accumulation) of the solid phase. It is known that the density of such environments is unequivocally related to the concentration of disperse phase, which is explained by the wide use of density meters, such as the death of the concentration of two-phase systems.

The peculiarity of its movement in a two-phase environment in a vibratory field is that the dispersion dances with some displacement compared to the movement of the dispersion medium (liquid) as a result of the inertia of the phase (solid particles) and as a result of the action of friction forces: the relationship between the amplitude of the oscillations of liquid and solid particles is As a result of the influence of these factors, the degree characteristic of the density meter for suspensions differs from the characteristic for homogeneous liquids with the appearance of such a formula.

The choice of these or other converters of the concentration of suspensions is primarily due to the ability of the sensitive element to prevent the deposition of solid particles inside or outside it. Therefore, mechanical resonators should not have sharp bends or stagnant zones, they should be accessible for periodic cleaning or washing.

These requirements are met by single-layer resonators, including step-by-step variable cross-section single-layer resonators.

In recent years, designers of vibration-frequency Densitometers have been searching for new forms of pipe resonators for working with liquids under pressure. At the same time, designers try not to use flexible connecting elements, similar to silicones, which leads to the coordinated mechanical exchange of external structures of the resonator. However, the refusal to use flexible connecting elements leads to a decrease in the quality coefficient of the mechanical oscillation system. In this regard, the use of single-layer resonators of stepped-variable cross-section allows to avoid the reduction of the quality coefficient as a result of refusal to use elastic connecting elements, i.e. increase the quality coefficient.

Of particular interest is the possibility of using monorail resonators to measure the density of granular shaped substances. There are several types of granular shaped matter to measure the density of seals, including their actual density. When using vibration-frequency Densitometers, in order to measure the actual density of granular media, the upper part of the resonator tube must go beyond the limits of the hardened part, and the lower part must be closed with a lid. The transmitter should be installed in the flow path of the devilish fluid medium. The involuntary environment that enters the vibrating resonator fills it by squeezing it. The transmitter indicators are recorded after some time after the filling process is completed by pressing the granular liquid medium into the resonator. After the measurement process is complete, the lid is opened and the resonator is discharged until the next measurement work is performed.

CONCLUSION

1. According to the results of analysis carried out from the literature, modern demands on liquid flow density meters were systematized. The perspectives of tubular resonator vibration-frequency densities are shown.
2. The physical basis of the work of vibration-frequency Densitometers was revealed as a result of the analysis that determining the accuracy of the device is its mechanical resonator, and its main parameter is the quality coefficient.
3. By replenishing the demand for single-layer resonators, the question was raised about the search for a new shaped resonator of high quality.
4. As a result of systematization of data on synthesis of forms of resonators for high-quality resonator vibration-frequency density meters, an algorithm has been proposed using electromechanical analogies method.
5. Using the proposed algorithm, a new resonator with a pipe-shaped stepped variable cross-section has been synthesized, since the two periphery of the pipe is made up of thick and central thin parts, forming a double symmetry by the center.
6. The exact mathematical model of the synthesized new resonator has been studied and developed in order to obtain arithmetic expressions. The condition of rational parameters selection of single-layer resonator of the stepped-variable cross-section has been found. This condition provides to improve the quality of the mechanical oscillation system by reducing the scattering energy falling on the places of attachment of the resonator to the housing.
7. The exact mathematical model of the synthesized new resonator has been studied and developed in order to obtain arithmetic expressions. The condition of rational parameters selection of single-layer resonator of the stepped-variable cross-section has been found. This condition provides to improve the quality of the mechanical oscillation system by reducing the

scattering energy falling on the places of attachment of the resonator to the housing.

8. The influence of factors affecting the frequency of resonator oscillations(temperature, pressure and flow rate of measured fluid) was analyzed. Determination of the frequency of their oscillations as a result of the influence of the resonator factors and calculation of possible reduction of the influencing factors are obtained.

9. In order to verify the main theoretical provisions in the work, experimental studies of a single-row stage-variable cross-section resonator were carried out. The results of experimental studies showed that experimental and computational data coincide (the Maximum error of reports does not exceed 10 percent), as well as improvement of quality of resonator with the previous design increased 2.33 times.

10. Based on the results of theoretical and experimental studies, the report of the main parameters of the single-beam resonator of the stage-variable cross-section and methodological recommendations of its selection were developed. In this case, the condition for ensuring the yield frequency of the empty tube and mimimumization of the oscillatory energy losses falling to the places of connection in the housing is taken into account.

List of published scientific articles on the topic of the dissertation.

1. Abdullayev I.M., Huseynov T.K., Amiraslanov B.Q. The bulk vibroamplitude method of measurement density of granular medium // Measurementand control of granular materials: Proceedings of the Fourth International Conference. – Shenyang, P.R.China, 1997, p. 147-148.

2. Abdullayev I, Huseynov T., Amiraslanov B. The synthesis of mechanical system vibrational densimeter // 8th International Machine Design and Production Conference: Conference Proceedings. – Ankara, 1998. – p. 129-135.

3. Гусейнов Т.К., Амирасланов Б.В. Математическая модель трубчатого резонатора для вибрационных плотномеров / Ученые записки АзТУ. – 1998, т. 6, № 5, с. 215-220.

4. Hüseynov T.K., Abdullayev İ.M., Əmiraslanov B.Q. Elektromexaniki maye sıxlıqölçəni / AR Dövlət Elm və Texnika Komitəsi Milli patent ekspertizası mərkəzi, "Sənaye mülkiyyəti" rəsmi bülleteni, MKİ C 01 № 9/04, 1999 I hissə, №4, s. 129-130.

5. Guseynov T.K., Farhadov Z.I., Amiraslanov B.K., Shahverdieva S.S. Development of a technique of set-up camerton resonator vibrational sedimentemeter dusts with use of elements of the theory indistinct sets // Sumgayit; ecology and progress: abstracts of scientific-practical conference, Sumgayit, 1999, p.58-59.

6. Abdullayev I.M., Huseynov T.K., Amiraslanov B.K. The vibration-peak sensor unit of Water Cement Sturries density // Measurement and Control of granular materials (MCGM 2000),August 21-23, XIAN, P.R. China, 2000,p.60-63

7.Амирасланов Б.К. Определение условия минимизации реактивных сил в опорах камертонного резонатора с ветвями ступенчато-переменного сечения / Техника-2002, №2, с. 47-50.

8.Əmiraslanov B.Q. Vibrasiya-tezlik sıxlıqölçəninin keyfiyyətinin yüksəldilməsi üçün rezonatorun formasının seçilməsi // Aspirantların və gənc tədqiqatçıların IX Respublika Elmi Konfransının materialları, I hissə, Bakı, 11-12 iyun, 2003, s.28-29.

9.Əmiraslanov B.Q. Vibrasiya vericisinin göstəricisinə sıxlığı ölçülən mühitin qeyri-informativ parametrlərin təsirinin analizi // Aspirantların və gənc tədqiqatçıların IX Respublika Elmi Konfransının materialları, I hissə, Bakı, 11-12 iyun, 2003, s.28-29.

10. Əmiraslanov B.Q., Hüseynov T.K., Tağıyev R.T. Birborulu pilləvari-dəyişən kəsikli rezonatorlu vibrasiya-tezlik tezlikölçəninin temperatur xətasının azaldılması üsulları / SDU-nun elmi xəbərləri, 2004, №2, c. 78-81.

11. Гусейнов Т.К., Амирасланов Б.К. Анализ влияния скорости течения измеряемой жидкости на частоту колебаний трубчатого резонатора вибрационно-частотного плотномера жидкости // Современные проблемы информатизации,

кибернетики и информационных технологий: Труды II Республиканской научной конференции, Баку, 2004 г., т.3, с. 72-73.

12. Əmiraslanov B.Q.Vibrasiya-tezlik sıxlıqölçənlərinin mexaniki rəqs sisteminin keyfiyyət əmsalını ölçən cihaz / AzTU-nun Elmi əsərləri, 2004, №3, s.14.

13. Əmiraslanov B.Q. Dəqiqliyi yüksəldilmiş birborulu pilləvari-dəyişən kəsikli rezonatorlu vibrasiya-tezlik sıxlıqölçəni / Azərbaycan Ali Texniki Məktəblərinin xəbərləri, İnformatika və avtomatika, №4, 2004, s. 65-69.

14. Амирасланов Б.К., Гусейнов Т.К. Математическая модель однотрубного резонатора ступенчато-переменного сечения / Научные известия Сумгаитского Государственного Университета. № 4,т.5,2005,с.85-88.

15. Əmiraslanov B.Q. Keyfiyyət əmsalı yüksəldilmiş birborulu rezonatorlu vibrasiya-tezlik sıxlıqölçəninin tədqiqi // Aspirantların və Gənc tədqiqatçıların XI respublika Elmi Konfransının materialları, BDU, Bakı, 2006, s. 95-96.

16. Əmiraslanov B.Q. Yüksək keyfiyyətli pilləli-dəyişən en kəsikli birborulu rezenatorun eksperimental tədqiqi / AzTU-nun Elmi əsərləri, 2006, №4, s.45-47.

17. Гусейнов Т.К., Амирасланов Б.К., Абдуллаев И.М. Анализ системы возбуждения вибрационного плотномера / Известия Высших Технических Учебных Заведений Азербайджана. Метрология и приборостроение. Баку, 2007, №1(47), с.60-63.

18. Абдуллаев И.М., Гусейнов Т.К., Агаева Ф.Ш. Математическое обоснование вибрационно-частотного метода измерения жидкости // Riyaziyyatın tətbiqi məsələləri və yeni informasiya texnologiyaları. Respublika elmi konfransı.Sumqayıt. 2007, s.219-221

19**.** Пат. İ 2008 0025 от 28.01.2008 (Азербайджан). Резонансный датчик плотности /Т.К.Гусейнов, И.М.Абдуллаев, Б.К.Амирасланов.

20. Амирасланов Б.К., Гусейнов Т.К., Aslanova Z. Generalized mathematical model of sensitive elements of

vibration density measures of liquid // The second International Conference. "Problems of cybernetics and Informatics ", Baku , 2008, p. p 124-127.

21.Гусейнов Т.К., Амирасланов Б.К. Обобщенная математическая модель трубчатых резонаторов для вибрационно-частотных плотномеров жидких продуктов / Прикаспийский журнал: управление и высокие технологии. Астрахань, 2009, №4(8), с.11-14.

22. Гусейнов Т.К., Амирасланов Б.К., Оруджева Г.Э., Тагиева Т.А. Обобщённая математическая модель трубчатых резонаторов вибрационно-частотных плотномеров нефтепродуктов // Труды международной конференции «Научно-технический прогресс и современная авиация» том 2, Баку, 2009, с.63-65.

23. Гусейнов Т.К., Амирасланов Б.К. Тагиева Т.А., Джафарова Ш.М., Оруджева Г.Э. Синтез высокодобротного механического резонатора с помощью электромеханических аналогий с использованием программы Electronics Workbench / Научные известия Сумгаитского Государственного Университета. 2010, № 1, т.10, с. 49-53.

24. Hüseynov T.K., Əmiraslanov B.Q., Tağıyeva T.A., Cəfərova Ş.M., Orucova G.E. Vibrasiya-tezlik sıxlıqölçənləri üçün rezonatorun riyazi modeli / SDU-nun elmi xəbərləri, 2010, №3, səh. 61-65.

25.Əmiraslanov B.Q.,Tağıyeva T.A.,Əliyeva A.Q.Birborulu rezonatorlu vibrasiya sıxlıqölçəninin vericisinin konstruksiyasının işlənməsi / SDU-nun elmi xəbərləri,2013,№1, səh. 82-87.

26.Гусейнов Т.К., Амирасланов Б.К., Джафарова Ш.М., Оруджева Г.Э. Математическая модель резонатора вибрационного плотномера жидкости работающего в режиме свободных колебаний // Современные концепции научных исследований. VII международная научно-практическая конференция. Технические науки. Часть 1, Москва, 2014, с.11.

27. Гусейнов Т.К., Амирасланов Б.К., Тагиева Т.А., Садыгов З.А. Расчет собственных частот колебаний неоднородных трубчатых резонаторов вибрационных

плотномеров жидкости // Научные перспективы XXI века. Достижения и перспективы нового столетия. VI международная научно-практическая конференция. Технические науки. Часть 2, Новосибирск, 2014, стр.8-9.

28. Юсифов С.И., Мамедов Дж.Ф., Гусейнов Т.К., Амирасланов Б.К. Исследование влияния скорости течения измеряемой жидкости на частоту колебаний трубчатого резонатора вибрационно-частотного плотномера жидкости / Измерительная и вычислительная техника в технологических процессах. Хмельницкий национальный университет. 2017, №1(57), с.31-34.

29. Юсифов С.И., Амирасланов Б.К., Мамедова Г.А. Способ определения точности измерения и эксплуатации плотномеров в АСУ ТП. «Уфимский государственный нефтяной технический университет» //Международная научно-техническая конференция аспирантов и молодых ученых «Наука. Технология. Производство», г. Салават,10-12 мая, 2017, стр. 229.

30.Юсифов С.И., Амирасланов Б.К., Ибрагимова П.А. Экспериментальное исследование однотрубного резонатора ступенчато-переменного сечения с повышенной добротностью. «Уфимский государственный нефтяной технический университет» //Международная научно-техническая конференция аспирантов и молодых ученых «Наука. Технология. Производство», г. Салават,10-12 мая, 2017, стр. 230.

31.ЮсифовС.И.,AmiraslanovB.K.Анализ состояния раз работки вибрационных поточных плотномеров жидких сред // İnformasiya sistemləri və texnologiyalar: nailiyyətlər və perspektivlər. Beynəlxalq elmi konfransın materialları, Sumqayıt ş., 2018, s.50-51.

32.ƏmiraslanovB.Q.Vibrasiya-tezlik sıxlıqölçəninin rezonatorunun tədqiqi // İnformasiya sistemləri və texnologiyalar: nailiyyətlər və perspektivlər. Beynəlxalq elmi konfransın materialları, Sumqayıt ş., 2018, s.49-50.

33.Huseynov T.K., Amiraslanov B.K., Gadirova T.T., Abdulova N.A., Haciyeva K.R. Theoretical and experimental study of vibration-amplitude liquid densimeter on the basis of a high-quality tubular resonator // International Scientific and Technical Conference: SES-2019, Scopus preview. E3S Web of Conferences 124, 03004 (2019) г. Kazan, Russia, 2019, стр.18-20.

34.ЮсифовС.И., AmiraslanovB.K. Нечеткая система автоматической настройки вибрационно-частотного плотномера // İnformasiya sistemləri və texnologiyalar: nailiyyətlər və perspektivlər. Beynəlxalq elmi konfransın materialları, Sumqayıt ş., 2020, s.330-331.

35.Юсифов С.И., Фархадов З.И., Амирасланов Б.К. Система автоматической настройки вибрационно-частотного плотномера на основе нечеткой логики // Международной научно-технической конференции”, Пром-Инжиниринг”, г. Сочи, 2021, стр. 60-63.

36. Amiraslanov B.K., Abdulova N.A., Abdullayeva S.C., Huseynov A.S., Kravets A.İ.. Influence of the pressure of the measured liquid on the readings of vibration-frequency density sensors in the chemical industry // III International conference mip: engineering-2021: Advanced technologies in material science, mechanical and automation engineering, Scopus preview. E3S Web of Conferences, г. Krasnoyarsk, Russia, 2021, стр. 129-135.

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