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Original Article

Mathematical Models of Active Acoustic Impact on Diffusion in Reservoirs with Oil Hierarchical Inclusions and Additional Influence of Turbulence

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***Abstract** - During acoustic monitoring at a fixed frequency in a layered medium with inclusions of a hierarchical structure, responses with additional frequencies are observed in fluid-saturated hierarchical inclusions. The multitude of pulsations of various periods and amplitudes illustrates the complex internal structure of turbulent flows, which sharply differ in this respect from laminar flows. So, turbulent flows have a much greater ability to transfer momentum and therefore in many cases exert a much greater force effect on solid bodies flown around by a liquid or gas. Due to the presence of internal inhomogeneities, turbulent flows are able to scatter sound and electromagnetic waves passing through a liquid or gas and cause fluctuations in their amplitudes and phases. The listed properties of turbulent flows can be very important for many problems of natural science and technology. For a quantitative study of these effects, an algorithm has been developed in the form of an iterative process for solving a direct problem to consider a more detailed effect of turbulent fluid motion causing acoustic emission in a reservoir containing fluid-saturated inclusions of a hierarchical type. The simulation results can be used for monitoring studies of fluid recovery control in oil fields*.

Keywords *— hierarchical medium, acoustic field, iterative algorithm, effects of turbulent diffusion, oscillatory disturbances in a fluid-saturated inclusion.*

I. INTRODUCTION

In geoacoustics, the laws of the formation and propagation of elastic waves in the earth's crust are studied. The frequencies of such waves are in the range from 0.1 to 10^6 Hz. The study of the parameters of these waves and their relationship with the properties and structure of the rock massif make it possible to control the process of extracting hydrocarbons. Its implementation consists in the adequacy and efficiency of information about the geodynamic processes occurring at the current time. In accordance with the basic principles of geoacoustics, natural and induced acoustic emission serves as a source of elastic waves in field studies. Acoustic emission is the radiation of elastic waves that occurs during the restructuring of the internal structure of a solid. Acoustic emission (AE) appears during plastic deformation, the appearance and development of defects (cracks), during phase transformations in the crystal lattice of a solid. In a fluid-saturated porous medium, the occurrence of AE is associated with the movement of fluid in the pore space, the emergence and destruction of hydrodynamic barriers, and phase transitions of multicomponent formation fluids. The purpose of the AE study method is to obtain information about the processes occurring inside the material of the productive formation in the well. This method has an important advantage over other geophysical methods due to its high resolution in the frequency range [1]. At the same time, to understand the processes in a saturated porous medium and to build adequate models, it is not enough just to have a linear relationship between the AE and the dynamic processes of a medium that has the properties of a nonlinear system. A fundamental feature of a nonlinear medium is the interaction of a limited number of waves associated with the resonance conditions of frequencies and wave vectors [2]. In this paper, we will consider in more detail the effect of turbulent fluid motion causing acoustic emission in a reservoir containing fluid-saturated inclusions of a hierarchical type.

II. TURBULENT DIFFUSION

Turbulent diffusion is the transfer of matter in space due to the turbulent motion of the medium. Turbulence exists in almost all currents, regardless of whether they occur in natural conditions or in modern technical systems. Therefore, great efforts have been expended to try to understand this very complex physical phenomenon and to develop empirical and mathematical models for its description and reliable calculation of the characteristics of turbulent flows. In the book [3], some issues of the transition from laminar to turbulent flow are considered, as well as some models of turbulence of varying degrees of complexity. Turbulent motion is chaotic. The term "chaotic" in this case is almost synonymous with the word "turbulent". The chaos is the main property of such a movement. The dynamics of vortex motion is central to the theory of turbulence. The nature of the interaction of vortices almost completely determines the fine structure of turbulence; moreover, the movement is often acquires a large-scale coherent structure. The mechanism of the onset of turbulence is associated with a cascade process of vortex fragmentation in turbulent flows and determines the transfer of energy from the main motion to small-scale vortex formations in which viscous dissipation occurs. The total energy of large-scale eddies in this process remains approximately constant [3]. A wide range of vortex size variation is due to the vortex tube stretching mechanism, under the action of which vortices of approximately the same size are successively transformed into vortices of the next order of smallness. This process has a cascade nature: the size of the vortices gradually decreases, and the energy of the main flow is transferred to movements of smaller scales; the minimum scale is reached when the energy of the vortices is dissipated under the direct action of viscous stresses. It is usually assumed that vortices of substantially different sizes do not directly affect each other and only vortices of comparable size can exchange energy. It was found that viscosity weakly affects the motion and structure of the main turbulent flow; however, its influence becomes decisive at the final stage of turbulence energy dissipation, when the velocity gradients in shallow vortices disappear under the action of viscous stresses. [4] When smaller vortices are subjected to the strain rates created by larger vortices, energy transfer occurs between the vortices. In the process of deformation, the vorticity of smaller vortices increases and, accordingly, their energy increases due to the energy of larger vortices. Thus, energy is transferred from larger eddies to smaller eddies. Another effective means of describing turbulence is the spectral analysis method. Spectral analysis makes it possible to describe the exchange of kinetic energy corresponding to vortices of different sizes or different frequencies of pulsations in turbulent motion. There are two types of spectral functions that are of interest in the analysis of turbulence: frequency spectra and spectra in wavenumber space. We will consider frequency spectra as they are easier to understand. The lower the frequency of the vortices (i.e., the larger the size of the vortices), the greater the kinetic energy contained in them. Consequently, the bulk of the kinetic energy is contained in large eddies [4]. However, turbulence cannot be described by a set of discrete eddies, as suggested above, since the turbulent flow contains eddies whose sizes are continuously distributed in a certain range. To take this fact into account, let us complicate the considered hypothetical flow in one more respect, as a result of which the expansion of the non-periodic function in the Fourier integral will be obtained. (Size 10 & Normal)Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline.

III. BOREHOLE ACOUSTIC TESTING

Radiation of the acoustic field and reception of seismoacoustic emission signals (CAE in a wide frequency range is produced by devices located in one downhole geophysical device, which can move along the wellbore in the process of well testing with a given algorithm of the equipment operation [6]. The algorithm of the equipment operation consists in sequential execution operations to register microseismic background in the borehole, acoustic impact on the rock mass and re-registration of the ASS immediately after the impact.The energy of the induced acoustic emission, which is released during the acoustic impact, was determined by calculating the spectral energy density using the IntenGraph 2 program [6] using the example the acoustic emission signal in the productive formation BS10 of the terrigenous type of the Tevlino-Russkinskoe field, Western Siberia in the process of acoustic stimulation [6]. m of oil is several tens of percent relative to the background level. At the same time, individual events of acoustic emission in the form of single actions of emission sources occur randomly and have characteristic parameters of signal pulses of finite duration of a certain shape. In this case, the presence of discrete frequencies with a certain maximum energy value is clearly manifested. Spectral analysis of the acoustic emission signal with a duration of one second is performed using a windowed Fourier transform in a sliding window of a given length. The spectrogram shows a distinct discrete nature of the set of frequencies in the signal caused by acoustic emission. In this case, there is an increase in the energy of acoustic emission at discrete frequencies by several times in comparison with the microseismic background [1].

IV. TABLE I

Discrete frequencies from the spectrum of the emission signal at a depth of 2840 meters.

“2840m”/i	ω(i)*Hz*
1	1259
2	2648
3	4048
4	6007
5	6826
6	8290
7	9506
8	10389
9	11509

In the column ω (i) is the frequency from the experimental spectrum.

V. ALGORITHM OF MODELING SOUND ACOUSTIC WAVE PROPAGATION IN A LAYERED BLOCK PLASTIC MEDIUM WITH HIERARCHICAL FLUID-SATURATED INCLUSIONS AFTER ACTIVE FREQUENCY EXCITATION AND ADDITIONAL TURBULENT INFLUENCE.

The paper [7] describes an algorithm for modeling sound diffraction by a two-dimensional elastic hierarchical inclusion located in the J-th layer of an N-layered medium. $G_{Sp,j}(M,M^0)$ - source function of the seismic field, the boundary value problem for which is formulated in [8]; $k_{1ji}^2=\omega^2(\sigma_{ji}/\lambda_{ji})$ - wavenumber for a longitudinal wave; in the above expression, the index *ji* denotes the belonging of the properties of the medium inside the inhomogeneity, *ja* - outside the inhomogeneity; λ is the Lamé constant; σ is the density of the medium; ω - circular frequency of excitation; $\bar{u}=\operatorname{grad}\varphi$ - vector of displacements; φ^0 is the potential of a normal seismic field in a layered medium by the absence of heterogeneity: $\varphi_{ji}^0=\varphi_{ja}^0$. l = 1… L is the rank of the hierarchy of inclusions. Let l = 1. $\lambda_{ji}=\lambda_{ja}+\omega_1\lambda_{ji(l=1)}$ [9] .ω1 = 1259Hz (table 1.) - the frequency of large turbulent vortices, $\varphi^0_{(l=1)-1}$ corresponds to the exciting field at the reservoir level. The system of equations [7] can be rewritten as (1):

$$\begin{gathered}\frac{(k^2_{1ji(l=1)}-k^2_{1j})}{2\pi}\iint\limits_{Sc(l=1)}\varphi_{(l=1)}(M)G_{Sp,j}(M,M^0)d\tau_M+\frac{\sigma_{ja}}{\sigma_{ji(l=1)}}\varphi^0_{(l=1)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=1)})}{\sigma_{ji(l=1)}2\pi}\oint\limits_{C(l=1)}G_{Sp,j}\frac{\partial\varphi_{(l=1)}}{\partial n}dc=\varphi_{(l=1)}(M^0),M^0\in S_{C(l=1)}\ ,\\ \frac{\sigma_{ji(l=1)}(k^2_{1ji(l=1)}-k^2_{1j})}{\sigma(M^0)2\pi}\iint\limits_{Sc(l=1)}\varphi_{(l=1)}(M)G_{Sp,j}(M,M^0)d\tau_M+\varphi^0_{(l=1)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=1)})}{\sigma(M^0)2\pi}\oint\limits_{C(l=1)}G_{Sp,j}\frac{\partial\varphi_{(l=1)}}{\partial n}dc=\varphi_{(l=1)}(M^0),M^0\notin S_{C(l=1)}\ .\end{gathered}\tag{1}$$

l = l + 1, i.e. l = 2, inclusions *Sc* (l = 2) and *C* (l = 2) are located inside *Sc* (l = 1) and *C* (l = 1), respectively, $\lambda_{ji}=\lambda_{ji(l=1)}+\omega_2\lambda_{ji(l=2)}$, ω_2 = 2648 *Hz* (table 1.) frequency of large turbulent vortices. $\varphi^0_{(l=2)-1}=\varphi_{(l=1)}$ System of equations (1) will be rewritten as:

$$\begin{gathered}\frac{(k^2_{1ji(l=2)}-k^2_{1j})}{2\pi}\iint\limits_{Sc(l=2)}\varphi_{(l=2)}(M)G_{Sp,j}(M,M^0)d\tau_M+\frac{\sigma_{ja}}{\sigma_{ji(l=2)}}\varphi^0_{(l=2)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=2)})}{\sigma_{ji(l=2)}2\pi}\oint\limits_{C(l=2)}G_{Sp,j}\frac{\partial\varphi_{(l=2)}}{\partial n}dc=\varphi_{(l=2}(M^0),M^0\in S_{C(l=2)}\ ,\\ \frac{\sigma_{ji(l=2)}(k^2_{1ji(l=2)}-k^2_{1j})}{\sigma(M^0)2\pi}\iint\limits_{Sc(l=2)}\varphi_{(l=2)}(M)G_{Sp,j}(M,M^0)d\tau_M+\varphi^0_{(l=2)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=2)})}{\sigma(M^0)2\pi}\oint\limits_{C(l=2)}G_{Sp,j}\frac{\partial\varphi_{(l=2)}}{\partial n}dc=\varphi_{(l=2)}(M^0),M^0\notin S_{C(l=2)}\ .\end{gathered}\tag{2}$$

l = l + 1, i.e. l = 3, inclusions *Sc* (l = 3) m and *C* (l = 3) *m* are located inside *Sc* (l = 2) and *C* (l = 2), fluid-saturated inclusions under the influence of large eddies, *m* = 1, ... *M*, respectively, $\lambda_{ji}=\lambda_{ji(l=2)}+\omega_3\lambda_{ji(l=3)}$ ω_3 = 4048*Hz* (table 1.) frequency of large turbulent vortices. $\varphi^0_{(l=3)-1}=\varphi_{(l=2)}$ The system of equations (2) will be rewritten as [10]:

$$\begin{gathered}\sum_{m=1}^{M}\{\frac{(k^2_{1ji(l=3)m}-k^2_{1j})}{2\pi}\iint\limits_{Sc(l=3)m}\varphi_{(l=3)m}(M)G_{Sp,j}(M,M^0)d\tau_M+\\+\frac{\sigma_{ja}}{\sigma_{ji(l=3)m}}\varphi^0_{(l=3)-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=3)m})}{\sigma_{ji(l=3)m}2\pi}\oint\limits_{C(l=3)m}G_{Sp,j}\frac{\partial\varphi_{(l=3)m}}{\partial n}dc=\\=\varphi_{(l=3)m}(M^0)+(\alpha p_2)_m\},M^0\in S_{C(l=3)m}\ ,\\ \sum_{m=1}^{M}\left\{\begin{aligned}&\frac{\sigma_{ji(l=3)m}(k^2_{1ji(l=3)m}-k^2_{1j})}{\sigma(M^0)2\pi}\iint\limits_{Sc(l=3)}\varphi_{(l=3)m}(M)G_{Sp,j}(M,M^0)d\tau+\varphi^0_{(l=3)-1}(M^0)-\\&-\frac{(\sigma_{ja}-\sigma_{ji(l=3)})}{\sigma(M^0)2\pi}\oint\limits_{C(l=3)}G_{Sp,j}\frac{\partial\varphi_{(l=3)m}}{\partial n}dc=\varphi_{(l=3)m}(M^0),\end{aligned}\right\},\\ ,M^0\notin S_{C(l=3)m},m=1,...,M.\end{gathered}\tag{3}$$

$(\alpha p_2)_m=((1-\chi-\frac{K}{K_0})p_2)_m$; -*K* - modulus of comprehensive compression, χ - porosity, K_0 - true modulus of phase compressibility, pore hydrostatic pressure p_2 for the *m*-th fluid-saturated inclusion. l = l + 1, i.e. l = 4, inclusions *Sc* (l = 4) and *C* (l = 4) are inside *Sc* (l = 2) and *C* (l = 2), respectively, $\lambda_{ji}=\lambda_{ji(l=2)}+\omega_4\lambda_{ji(l=4)}$ ω_4 = 6007*Hz* (Table 1.) $\varphi^0_{(l=4)-1}=\varphi_{(l=2)}$ The system of equations (2) will be rewritten as:

$$\begin{gathered}\frac{(k^2_{1ji(l=4)}-k^2_{1j})}{2\pi}\iint\limits_{Sc(l=4)}\varphi_{(l=4)}(M)G_{Sp,j}(M,M^0)d\tau_M+\frac{\sigma_{ja}}{\sigma_{ji(l=4)}}\varphi^0_{(l=4)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=4)})}{\sigma_{ji(l=4)}2\pi}\oint\limits_{C(l=4)}G_{Sp,j}\frac{\partial\varphi_{(l=4)}}{\partial n}dc=\varphi_{(l=4}(M^0),M^0\in S_{C(l=4)}\ ,\\ \frac{\sigma_{ji(l=4)}(k^2_{1ji(l=4)}-k^2_{1j})}{\sigma(M^0)2\pi}\iint\limits_{Sc(l=4)}\varphi_{(l=4)}(M)G_{Sp,j}(M,M^0)d\tau_M+\varphi^0_{(l=4)-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=4)})}{\sigma(M^0)2\pi}\oint\limits_{C(l=4)}G_{Sp,j}\frac{\partial\varphi_{(l=4)}}{\partial n}dc=\varphi_{(l=4)}(M^0),M^0\notin S_{C(l=4)}\ .\end{gathered}\tag{4}$$

l = l + 1, i.e. l = 5, inclusions *Sc* (l = 5) *mm* and *C* (l = 5) *mm* are inside *Sc* (l = 2) and *C* (l = 2), fluid-saturated inclusions under by the action of mean vortices *mm* = 1,… *MM*, respectively, $\lambda_{ji}=\lambda_{ji(l=2)}+\omega_5\lambda_{ji(l=5)}$, ω_5 = 6826*Hz* (table 1.) $\varphi^0_{(l=5)-1}=\varphi_{(l=2)}$ The system of equations (2) will be rewritten as [10]:

$$\begin{gathered}\sum_{1}^{MM}\{\frac{(k^2_{1ji(l=5)mm}-k^2_{1j})}{2\pi}\iint\limits_{Sc(l=5)mm}\varphi_{(l=5)mm}(M)G_{Sp,j}(M,M^0)d\tau+\\+\frac{\sigma_{ja}}{\sigma_{ji(l=5)mm}}\varphi^0_{(l=5)-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=5)mm})}{\sigma_{ji(l=5)mm}2\pi}\oint\limits_{C(l=5)mm}G_{Sp,j}\frac{\partial\varphi_{(l=5)mm}}{\partial n}dc=\\=\varphi_{(l=5)mm}(M^0)+(\alpha p_2)_{mm}\},M^0\in S_{C(l=5)mm}\ ,\\ \sum_{mm=1}^{MM}\left\{\begin{aligned}&\frac{\sigma_{ji(l=5)mm}(k^2_{1ji(l=5)mm}-k^2_{1j})}{\sigma(M^0)2\pi}\iint\limits_{Sc(l=5)mm}\varphi_{(l=5)mm}(M)G_{Sp,j}(M,M^0)d\tau+\varphi^0_{(l=5)mm-1}-\\&-\frac{(\sigma_{ja}-\sigma_{ji(l=5)mm})}{\sigma(M^0)2\pi}\oint\limits_{C(l=5)mm}G_{Sp,j}\frac{\partial\varphi_{(l=5)}}{\partial n}dc=\varphi_{(l=5)mm}(M^0),\end{aligned}\right\}\\ ,M^0\notin S_{C(l=5)mm}\ mm=1,..,MM.\end{gathered}\tag{5}$$

$(\alpha p_2)_{mm} = ((1-\chi - \frac{K}{K_0})p_2)_{mm}$ $l = l + 1$, i.e. $l = 6$, inclusions *Sc* ($l = 6$) mn and *C* ($l = 6$) *mn* are inside *Sc* ($l = 2$) and *C* ($l = 2$), fluid-saturated inclusions under by the action of mean vortices smaller than the previous ones *mm*, *mn* = 1,… *MN*, respectively, $\lambda_{ji} = \lambda_{ji(l=2)} + \omega_6 \lambda_{ji(l=6)}$, ω_6 = 8290*Hz* (table 1.) $\varphi^0_{(l=6)-1} = \varphi_{(l=2)}$ The system of equations (1) will be rewritten in the form [10]:

$$\sum_{mn=1}^{MN}\{\frac{(k^2_{1ji(l=6)mn}-k^2_{1j})}{2\pi}\iint_{Sc(l=6)mn}\varphi_{(l=6)mn}(M)G_{Sp,j}(M,M^0)d\tau + \tag{6}$$
$$+\frac{\sigma_{ja}}{\sigma_{ji(l=6)mn}}\varphi^0_{(l=6)mn-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=6)mn})}{\sigma_{ji(l=6)mn}2\pi}\oint_{C(l=6)mn}G_{Sp,j}\frac{\partial\varphi_{(l=6)mn}}{\partial n}dc =$$
$$=\varphi_{(l=6)mn}(M^0)+(\alpha p_2)_{mn}\}, M^0\in S_{C(l=6)mn},$$
$$\sum_{mn=1}^{MN}\left\{\begin{array}{l}\frac{\sigma_{ji(l=6)}(k^2_{1ji(l=6)mn}-k^2_{1j})}{\sigma(M^0)2\pi}\iint_{Sc(l=6)mn}\varphi_{(l=6)mn}(M)G_{Sp,j}(M,M^0)d\tau+\\+\varphi^0_{(l=6)mn-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=6)mn})}{\sigma(M^0)2\pi}\oint_{C(l=6)mn}G_{Sp,j}\frac{\partial\varphi_{(l=6)mn}}{\partial n}dc=\varphi_{(l=6)mn}(M^0)\end{array}\right\}$$
$$, M^0\notin S_{C(l=6)mn}\;\; mn=1,..,MN.$$

$$\sum_{nm=1}^{NM}\{\frac{(k^2_{1ji(l=7)nm}-k^2_{1j})}{2\pi}\iint_{Sc(l=7)nm}\varphi_{(l=7)nm}(M)G_{Sp,j}(M,M^0)d\tau +$$
$$+\frac{\sigma_{ja}}{\sigma_{ji(l=7)nm}}\varphi^0_{(l=7)nm-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=7)nm})}{\sigma_{ji(l=7)nm}2\pi}\oint_{C(l=7)nm}G_{Sp,j}\frac{\partial\varphi_{(l=7)nm}}{\partial n}dc =$$
$$=\varphi_{(l=7)nm}(M^0)+(\alpha p_2)_{nm}\}, M^0\in S_{C(l=7)nm},$$
$$\sum_{nm=1}^{NM}\left\{\begin{array}{l}\frac{\sigma_{ji(l=7)}(k^2_{1ji(l=7)}-k^2_{1j})}{\sigma(M^0)2\pi}\iint_{Sc(l=7)nm}\varphi_{(l=7)nm}(M)G_{Sp,j}(M,M^0)\\+\varphi^0_{(l=7)nm-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=7)nm})}{\sigma(M^0)2\pi}\oint_{C(l=7)nm}G_{Sp,j}\frac{\partial\varphi_{(l=7)nm}}{\partial n}dc=\\=\varphi_{(l=7)nm}(M^0),\end{array}\right\}$$
$$, M^0\notin S_{C(l=7)nm}\;\; nm=1,..,NM. \tag{7}$$

$(\alpha p_2)_{mn} = ((1-\chi - \frac{K}{K_0})p_2)_{mn}$ $l = l + 1$, i.e. $l = 7$, inclusions *Sc* ($l = 7$) *nm* and *C* ($l = 7$) *nm* are inside *Sc* ($l = 1$) and *C* ($l = 1$), fluid-saturated inclusions under by the influence of average vortices, smaller than the previous ones, *nm* = 1,… *NM*, respectively, $\lambda_{ji} = \lambda_{ji(l=1)} + \omega_7 \lambda_{ji(l=7)}$, ω_7 = 9506*Hz* (table 1.) $\varphi^0_{(l=7)-1} = \varphi_{(l=1)}$.The system of equations (1) can be rewritten as [10].

$(\alpha p_2)_{nm} = ((1-\chi - \frac{K}{K_0})p_2)_{nm}$ $l = l + 1$, i.e. $l = 8$, inclusions *Sc* ($l = 8$) *m* 'and *C* ($l = 8$) *m'* are inside *Sc* ($l = 4$) and *C* ($l = 4$), fluid-saturated inclusions under the influence of small eddies smaller than previous m '= 1,… M', respectively, $\lambda_{ji} = \lambda_{ji(l=4)} + \omega_8 \lambda_{ji(l=8)m'}$, ω_8 = 10389*Hz* (table 1.) $\varphi^0_{(l=8)-1} = \varphi_{(l=4)}$ The system of equations (1) will be rewritten as [10]:

$$\sum_{m'=1}^{M'}\{\frac{(k^2_{1ji(l=8)m'}-k^2_{1j})}{2\pi}\iint_{Sc(l=8)m'}\varphi_{(l=8)m'}(M)G_{Sp,j}(M,M^0)d\tau +$$
$$+\frac{\sigma_{ja}}{\sigma_{ji(l=8)m'}}\varphi^0_{(l=8)m'-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=8)m'})}{\sigma_{ji(l=8)m'}2\pi}\oint_{C(l=8)m'}G_{Sp,j}\frac{\partial\varphi_{(l=8)m'}}{\partial n}dc =$$
$$=\varphi_{(l=8)m'}(M^0)+(\alpha p_2)_{m'}\}, M^0\in S_{C(l=8)m'}, \tag{8}$$
$$\sum_{m'=1}^{M'}\left\{\begin{array}{l}\frac{\sigma_{ji(l=8)m'}(k^2_{1ji(l=8)m'}-k^2_{1j})}{\sigma(M^0)2\pi}\iint_{Sc(l=8)m'}\varphi_{(l=8)m'}(M)G_{Sp,j}(M,M^0)d\tau+\\+\varphi^0_{(l=8)m'-1}(M^0)-\\-\frac{(\sigma_{ja}-\sigma_{ji(l=8)m'})}{\sigma(M^0)2\pi}\oint_{C(l=8)m'}G_{Sp,j}\frac{\partial\varphi_{(l=8)m'}}{\partial n}dc==\varphi_{(l=8)m'}(M^0),\end{array}\right\}$$
$$M^0\notin S_{C(l=8)m'}\;\; m'=1,..,M'.$$

$(\alpha p_2)_{m'} = ((1-\chi - \frac{K}{K_0})p_2)_{m'}$; *K*- Module of comprehensive compression, χ - porosity, K_0 true of compressibility module, porose hydrostatic pressure p_2 for *m*'-fluid-saturated inclusion. $l = l + 1$. $l = 9$, the inclusion of *Sc* ($l = 9$) *MMM* and *C* ($l = 9$) *MMM* is inside *Sc* ($l = 3$) and *C* ($l = 3$), *MMM* = 1, ...*mmm*, respectively, $\lambda_{ji} = \lambda_{ji(l=3)} + \omega_9 \lambda_{ji(l=9)mmm}$, ω_9 = 11509*Hz* (Table1.) $\varphi^0_{(l=9)mmm-1} = \varphi_{(l=3)mmm}$. The system of equations (1) rewrite in the form [10]:

$$\sum_{mmm=1}^{MMM}\{\frac{(k^2_{1ji(l=9)mmm}-k^2_{1j})}{2\pi}\iint_{Sc(l=9)mmm}\varphi_{(l=9)mmm}(M)G_{Sp,j}(M,M^0)d\tau +$$
$$+\frac{\sigma_{ja}}{\sigma_{ji(l=9)mmm}}\varphi^0_{(l=9)mmm-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=9)mmm})}{\sigma_{ji(l=9)mmm}2\pi}\oint_{C(l=9)mmm}G_{Sp,j}\frac{\partial\varphi_{(l=9)mmm}}{\partial n}dc = \tag{9}$$
$$=\varphi_{(l=9)mmm}(M^0)+(\alpha p_2)_{mmm}\}, M^0\in S_{C(l=9)mmm},$$
$$\sum_{mmm=1}^{MMM}\left\{\begin{array}{l}\frac{\sigma_{ji(l=9)mmm}(k^2_{1ji(l=9)mmm}-k^2_{1j})}{\sigma(M^0)2\pi}\iint_{Sc(l=9)mmm}\varphi_{(l=9)mmm}(M)G_{Sp,j}(M,M^0)d\tau+\\+\varphi^0_{(l=9)mmm-1}(M^0)-\frac{(\sigma_{ja}-\sigma_{ji(l=9)mmm})}{\sigma(M^0)2\pi}\oint_{C(l=9)mmm}G_{Sp,j}\frac{\partial\varphi_{(l=9)mmm}}{\partial n}dc=\end{array}\right\}$$
$$=\varphi_{(l=9)mmm}(M^0), M^0\notin S_{C(l=9)mmm}, mmm=1,...,MMM.$$

$(\alpha p_2)_{mmm} = ((1-\chi - \frac{K}{K_0})p_2)_{mmm}$; *K*- module of comprehensive compression, χ -porosity, K_0 true of compressibility module, porose hydrostatic pressure p_2 for MMM-th fluid-saturated inclusion.

VI. CONCLUSIONS

Thus, acoustic emission in the porous plastic medium of collectors has the ability of permanent radiation. The main feature of acoustic emission is the reflection of stress relaxation and high sensitivity to external influences. In the case of a pore medium saturated with fluid, the generation of the caused radiation of elastic energy is adequately associated with its properties and the condition and the effect of the turbulent movement of the fluid in the tank, which leads to the additional movement of hierarchical fluid-saturated inclusions. Using the data of Table 1, a variant of the system of algorithms for structural rearrangement of a nonlinear two-phase porous medium after its dynamic excitation is constructed. The data are taken from the table of resonant frequencies and a sequence of rank adjustment to form a set of non-interacting fluid-saturated inclusions embedded in a porous medium having plastic properties. Such a system of algorithms is designed for the first time. The further development of this system of algorithms will be made to complication of the interpretation model, similar to how it was done in [11].

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