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# Determination of the Amplitude - Frequency Characteristics of the Well Pressure Preventing the Destruction of Wellbore Rocks

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DETERMINATIONOFTHEAMPLITUDEFREQUENCYCHARACTERISTICSOFTHEWELLPRESSUREPREVENTINGTHEDESTRUCTIONOFWELLBOREROCKS

*Strictly as per the compliance and regulations of:*

# Determination of the Amplitude - Frequency Characteristics of the Well Pressure Preventing the Destruction of Wellbore Rocks

R. A. Hasanov [α], I. Y. Shirali [σ] & M. I. Kazimov [ρ]

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## I. Introduction

It is well-known that the need for maintaining hydrocarbon coefficient (> 35%) in the development of fields is below the world standards (> 35%), which is closely related to the maintenance and enhancement of the existing well stock. The drilling of additional wells, especially in the aquatic area and the increase in the UVA, requires additional costs for the efficient use of the existing well stock. This problem exacerbates the problem of long-term exploitation of bedding resources, which have been modified as a result of geomechanical processes, and the development of hard-to-extract and large-scale deposits. Since the solution of these problems is not possible with the use of relatively low cost vertical drilling practices, over the past few decades, the use of horizontal wells with large and divergent direction has been widely used in world practice.

## II. Problem Setting

About 80% of investments in the commissioning of new fields, development and delivery of products to the consumer falls on drilling. The funding will also be eliminated as a result of uncertainty in the management of complex and hazardous technological operations related to the increase of the drainage rate and the increase in oil supply through the proper design of the pipeline route. However, there are still many unresolved problems related to drilling wells (geological substantiation, selection of pipeline route and calculation of well structures), designing of technology and related technical equipment (constructive justification of wells), completion and mastering (development of filter nodes). [1-3].

Theoretical and experimental studies of the tensile state of mountain rocks [4-5] show that these problems are mainly deformation processes of laminated mountain rocks, which are considered as the most suitable model by the self-plastic model.

## III. Solution of the Problem

The loading and discharge stages of the volcanic self-plastic mountain rocks can be written according to the following differential equations:

- for the recovery process

$$m_H \frac{d^2\theta_H}{dt^2} + \eta \frac{d\theta_H}{dt} + k_H\theta_H \le P_H - P_b - \sigma_b \quad (1)$$

- for the exemption process

$$m_p \frac{d^2\theta_p}{dt^2} + \eta_p \frac{d\theta_p}{dt} + k_p\theta_p \le P_p - P_b - \sigma_{dm} \quad (2)$$

here and ther $\theta_H$ and $\theta_p -$ respectively, relative dimensional deformations for loading and unloading processes; $P_H, P_p -$ pressures arising from appropriate processes; $k_H, k_p -$ volume in these processes are compression modules; $P_\delta -$ side pressure of mountain rocks; $\sigma_{rp} -$ resistance to hydraulic fracturing of mountain rocks; $\sigma_{dm} -$ resistance of mountain rocks to tension ; $m_H = \frac{\pi D}{g} P_H, m_p = \frac{\pi D}{g} P_p -$ are the masses brought into the unit length of the tuber; $D -$ Diameter of well; $g -$ acceleration of gravity; $\eta, k -$ respectively, the coefficients that characterize the viscosity and elasticity of mountain rocks. In general, the relative deformation of the volume is defined as the best function of the pressure in the pipe:

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$$\theta_H = aP^b \qquad (3)$$

If the loading process is with residual deformation, then

$$\theta_p = \theta_0 + a_1 P_p^{b_1} \qquad (4)$$

Thus, the equilibrium equation of self-elastic mountain rocks (including some sands, mergers, shale etc.) in well conditions can be expressed in the following equation:

$$m\theta''(t) + \eta\theta'(t) + k\theta(t) + P_b - P_{hy} - \Delta P = 0 \qquad (5)$$

(5) represent a unique self-elastic environment model of mountain rocks and their direct contact with neutral drilling mud. The physical and mechanical interaction of mountain rocks with drilling mud is different and has not been studied until now.

It is well known that the pressure drop in the borehole

$$\Delta P = \gamma H - P_{lay} + P_{ялавя} \qquad (6)$$

is designated as.

Here is:

$\gamma$ – the specific gravity of the drilling mud;

$H$ – depth of well;

$P_{rop}$-- lay pressure;

$P_{ялавя}$ – an additional pressure that occurs in a single space.

Usually this pressure is assumed to be constant [4], in fact, the pressure of the drilling mud changes in a small space while performing various technological processes in the drilling process. Therefore, the following approximate dependencies can be assumed to change this pressure:

$$\Delta P = \gamma H - P_{lay} + P_{ялавя} \qquad (7)$$

$$P_{ялавя} = c\cos\omega t$$ , where

$C$ and $\omega$ – the amplitude and frequency of additional pressure changes, respectively.

In general, the pressure changes in a single space can be represented as the Furye sequence:

$$P_{ялавя}(l,t) = \sum_{-\infty}^{+\infty} A_H \exp(in\omega t), \qquad (8)$$

$$A_H = \frac{\omega}{2\pi}\int_{-\frac{\pi}{\omega}}^{\frac{\pi}{\omega}} f(t)\exp(in\omega t)dt, \qquad (n = 0;\pm1;\pm2...) \qquad (9)$$

For simplifications, we accept that these variables are subject to the expression (7).

(6) and (7) if we take into account (5)

$$(A + B\cos\omega t)\theta''(t) + \eta\theta'(t) + k\theta(t) = F(t) \qquad (10)$$

(10) in the equation

$$A = \frac{\pi D}{g}(\gamma H - P_{lay}),$$
$$B = \frac{\pi Dc}{g}, \qquad (11)$$
$$F(t) = P_{hy} + \gamma H - P_b - P_{lay} - c\cos\omega t.$$

Thus, it is clear that the dynamic stability of the boulders around the well is represented by a nonlinear linear differential equation with variable and periodic coefficients.

The periodic solution of 2T periodic equations (10) is sought in the following equation:

$$\theta(t) = a_1\sin\frac{\omega t}{2} + b_1\cos\frac{\omega t}{2} + ... \qquad (12)$$

Given the equation (12) and zeroing the coefficients $\sin k\omega t$ və $\cos k\omega t$ of the same set, we construct the system of algebraic equations below:

$$a_1\left(k - A\frac{\omega^2}{4} + \frac{1}{2}B\frac{\omega^2}{4}\right) - b_1\eta\frac{\omega}{2} = 0,$$
$$b_1\left(k - A\frac{\omega^2}{4} - \frac{1}{2}B\frac{\omega^2}{4}\right) - a_1\eta\frac{\omega}{2} = 0. \qquad (13)$$

The existence of periodic solutions of the equation Birzins different from zero is conditioned by the fact that the determinant of the conditional (13) system is zero. Using this condition, we obtain the following critical frequency equations:

$$\begin{vmatrix} k - A\frac{\omega^2}{4} + \frac{1}{2}B\frac{\omega^2}{4} & -\eta\frac{\omega^2}{4} \\ \eta\frac{\omega^2}{4} & k - A\frac{\omega^2}{4} - \frac{1}{2}B\frac{\omega^2}{4} \end{vmatrix} = 0 \qquad (14)$$

From the Determinant

$$\omega_{1,2} = \sqrt{\frac{4kA - 2\eta \pm 2\sqrt{\eta^4 + 4k^2B^2 - 4kA\eta^2}}{A^2 - 0{,}25B^2}} \qquad (15)$$

For all of the values within the range defined by the formula (15), the amplitudes obtained from the uniform equation solutions are infinitely increasing. (15) The formulas allow for the amplitude and frequency of the additional pressure changes in the low-pressure space, which causes the volatile state of the wells, that is, in these pressure changes the inlet tubes are inevitable. For absolute elastics, that is, for the case $\eta = 1$

$$\omega_{1,2} = 2\sqrt{\frac{k(A \pm B)}{A^2 - 0{,}25B^2}} \qquad (16)$$

that is, for absolute elastics, there is also an amplitude and frequency of extra pressure in the low-pressure space, which causes instability.

The following linear algebraic equations system as a result of the solution of periodic T-waves

$$\begin{aligned} &k \cdot b_0 - 0 \cdot a_2 - 0{,}5 \cdot B \cdot \omega^2 \cdot b_2 = 0, \\ &0 \cdot b_0 + \left(k - A\omega^2\right) \cdot a_2 - \eta\omega b_2 = 0, \\ &0 \cdot b_0 + \eta\omega a_2 + \left(k - A\omega^2\right) \cdot b_2 = 0. \end{aligned} \qquad (17)$$

and the solution of its determinant

$$\begin{vmatrix} k & 0 & -0{,}5B\omega^2 \\ 0 & k - A\omega^2 & -\eta\omega \\ 0 & \eta\omega & k - A\omega^2 \end{vmatrix} = 0 \qquad (18)$$

The following expression is used to change the frequency that determines the boundaries of the first instability region:

$$\omega_{3,4} = \frac{1}{A}\sqrt{kA - 0{,}5\eta^2 \pm \eta\sqrt{0{,}25\eta^2 - kA}} \qquad (19)$$

The analysis conducted was based on models that assumed linear variation of parameters. If the models include $\xi-$nonlinear viscosity coefficients and $\gamma-$nonlinear elasticity coefficients, the first equation is to use the equation where the nonlinear coefficients are:

$$(A + B\cos\omega t)\theta'' + \eta\theta' + \xi\theta^1\theta^2 + k\theta + \gamma\theta^3 = 0 \qquad (20)$$

The solution of equation (20) can be searched as 2T or T periodic (12) sequences. For this purpose, non-linear assemblies are divided into Furye ranks.
For periodic solutions with 2T periodicity

$$\xi\theta^1\theta^2 + \gamma\theta^3 = \Phi(a_1 b_1)\sin\frac{\omega t}{2} + \psi(a_1 b_1)\cos\frac{\omega t}{2} + \ldots, \quad (21)$$

$$\left.\begin{aligned} \Phi(a_1 b_1) &= \frac{\omega}{2\pi}\int_0^{4\pi\omega-1}\left(\xi\theta^1\theta^2 + \gamma\theta^3\right)\sin\frac{\omega t}{2}\,dt, \\ \psi(a_1 b_1) &= \frac{\omega}{2\pi}\int_0^{4\pi\omega-1}\left(\xi\theta^1\theta^2 + \eta\theta^3\right)\cos\frac{\omega t}{2}\,dt. \end{aligned}\right\} \qquad (22)$$

(21) and (22) based on the reports

$$\begin{aligned} &\xi\theta^1\theta^2 + \gamma\theta^3 = \frac{a^2}{4}(3\gamma a_1 + \xi\omega b_1)\sin\frac{\omega t}{2} + \frac{a^2}{4}(3\gamma b_1 + \xi\omega a_1)\cos\frac{\omega t}{2} + \ldots, \\ &a^2 = a_1^2 + b_1^2. \end{aligned} \qquad (23)$$

Given (22) and (23) (20), and if we accept the coefficients $\sin k\omega t$ və $\cos k\omega t$ of expression coefficients, then

$$\begin{aligned} &a_1\left(k - A\frac{\omega^2}{4} + \frac{1}{2}B\frac{\omega^2}{4}\right) - b_1\eta\frac{\omega}{4} + \frac{a^2}{4}(\gamma a_1 3 - \xi\omega b_1) = 0, \\ &b_1\left(k - A\frac{\omega^2}{4} - \frac{1}{2}B\frac{\omega^2}{4}\right) + a_1\eta\frac{\omega}{2} + \frac{a^2}{4}(3\gamma b_1 - \xi\omega a_1) = 0. \end{aligned} \qquad (24)$$

The condition of the existence of solutions of the system (24) that is different from zero is that its determinant is zero;

$$\begin{vmatrix} k - A\frac{\omega^2}{4} + \frac{a^2}{4}3\gamma + \frac{1}{2}B\frac{\omega^2}{4} & -\eta\frac{\omega}{2} - \frac{a^2}{4}\xi\omega \\ \eta\frac{\omega}{2} + \frac{a^2}{4}\xi\omega & k - A\frac{\omega^2}{4} + \frac{a^2}{4}3\gamma - \frac{1}{2}B\frac{\omega^2}{4} \end{vmatrix} = 0 \qquad (25)$$

From the opening of the determinant, we determine that

$$a = \sqrt{4\sqrt{\frac{g}{4P^2} - \frac{l}{P} - \frac{2g}{P}}}\,, \qquad (26)$$

where

$$\begin{aligned} &g = 6\gamma k + \eta\xi\omega^2 - 1{,}5\gamma\omega^2 A, \\ &P = 9\gamma^2 + \gamma^2\omega^2, \\ &l = k^2 - \frac{1}{2}k\omega^2 A + \frac{1}{4}\eta^2\omega^2 + \frac{1}{16}A^2\omega^4 - \frac{1}{64}B^2\omega^4 \end{aligned} \qquad (27)$$

Equations (25) and (26) determine the amplitude-frequency dependence of the main variables of equation (20).
(20) Unstable solutions of the equation are characterized by a lower curve of the resonance curve.
(25) Shows that if nonlinear constants are eliminated, then unsteady solutions are defined by the boundaries of linear theory, i.e., equations (15) and (16).

Let's investigate the coordinated mode of changes near the main resonance. (20) Solving equation

$$\theta(t) = a(t)\sin\frac{\omega t}{2} + b(t)\cos\frac{\omega t}{2} + \ldots, \qquad (28)$$

Let's look for it.
Here are $a(t), b(t)-$"authentic changing functions".

Considering equation (20) in equation (20), and following intervals, we construct the following equation system:

$$\begin{aligned} &(A - 0{,}5B)\left(a'' - \omega b' - 0{,}25\omega^2 a\right) + \eta\left(a' - 0{,}5\omega b\right) + ka + \Phi(a,b) = 0, \\ &(A + 0{,}5B)\left(b'' + \omega a' - 0{,}25\omega^2 b\right) + \eta\left(b' + 0{,}5\omega a\right) + kb + \Phi(a,b) = 0. \end{aligned} \qquad (29)$$

(29) The system of equations can be simplified according to the requirements of the method of "real variable functions". For this reason, if we do not take into account small collections in Schedule 2, then

$$(A-0{,}5B)(0{,}25\omega^2 a+\omega b')=\Phi(a,b)+ka-0{,}5\eta\omega b,$$
$$(A+0{,}5B)(0{,}25\omega^2 b-\omega a')=\psi(a,b)+kb+0{,}5\eta\omega a. \quad (30)$$

(30) shows that the relationships used for the set regimes are

$$a'(t)=b'(t)=0. \quad (31)$$

condition.

By excluding non-linear assemblies in the pre-decision system (30).

$$a(t)=\alpha\exp(ht),$$
$$b(t)=\beta\exp(ht). \quad (32)$$

can be used, where $\alpha,\beta,h-$are constant coefficients.

Given the expression (32) in (30), we have the following system of equations

$$[(A-0{,}5B)0{,}25\omega^2-k]\alpha+(\omega h+0{,}5\eta\omega)\beta=0,$$
$$[(A+0{,}5B)0{,}25\omega^2-k]\beta-(\omega h+0{,}5\eta\omega)\alpha=0. \quad (33)$$

We can set an index of increase (decrease) given the existence of solutions other than zero (32):

$$h=\pm\sqrt{0{,}015625B^2\omega^2-\left(0{,}25A-\frac{k}{\omega}\right)^2}-0{,}5\eta \quad (34)$$

$h-$positive prices correspond to an increase in the amplitude of the unresolved variables and a decrease in the negative value.

As a result, it is worth noting that based on studies [6] to clarify the effect of reflection changes on the deformation of mountain rocks, it has been found that there are three characteristic parts of the deformation change curves:

Unresolved deformation area, field of deformation and intensity of self-plastic deformation. Obviously, the deformations identified will be typical of a number of mountain rocks in general. Thus, using the results of the above analysis to determine the coefficients $k$ and $\eta$ and to determine the deformation profiles that can occur with the rocks, and to prepare proposals for their elimination.

In order to continue the study of mountain rock instability (10) let us determine the relative changes in volume relative deformation based on the solution of equation. Write this equation explicitly [3,6]:

$$(A+B\cos\omega t)\theta''(t)+\eta\theta'(t)+k\theta(t)=d+c\cos\omega t \quad (35)$$

$$d=\sigma_{qr}+\gamma H-P_B-P_{lay} \quad (36)$$

and seek its solution as follows:

- "2T" periodic solutions

$$\theta(t)=\sum_{n=1}^{\infty}\left(x_n\cos\frac{\omega t}{n}+y_n\sin\frac{\omega t}{n}\right), \quad (37)$$

- "T" periodic solutions

$$\theta(t)=\sum_{n=1}^{\infty}(x_n\cos n\omega t+y_n\sin n\omega t), \quad (38)$$

$x_n, y_n-$are the coefficients determined by the joint solution of equations(35), (37) and (38).

Let us investigate the characteristic case with periodic variations of "T". (38) We find that

$$\theta'(t)=\sum_{n=1}^{\infty}n\omega(y_n\cos n\omega t-x_n\sin n\omega t), \quad (39)$$

$$\theta''(t)=\sum_{n=1}^{\infty}n\omega^2(x_n\cos n\omega t+y_n\sin n\omega t), \quad (40)$$

Considering (38) - (40) in (35), we create an infinite linear algebraic equation system for $x_n, y_n$ to sum the coefficients $\cos k\omega t$ və $\sin k\omega t$ to zero:

$$x_n, y_n;$$

$$(k-\omega^2 A)x_1-\eta\omega y_1-\omega^2 B\left(4\cdot\frac{1}{2}x_2\right)=c,$$

$$[k-\omega^2 A(4)]x_2-\eta\omega 2y_2-\omega^2 B\left(1\cdot\frac{1}{2}x_1+9\cdot\frac{1}{2}x_3\right)=0,$$

$$[k-\omega^2 A(9)]x_3-\eta\omega 3y_3-\omega^2 B\left(4\cdot\frac{1}{2}x_2+16\cdot\frac{1}{2}x_4\right)=0,$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$\left[k-\omega^2 A(n)\right]x_n-\eta\omega(n)y_n-\omega^2 B\left[(n-1)^2\cdot\frac{1}{2}x_{n-1}+(n+1)^2\cdot\frac{1}{2}x_{n+1}\right]=0,$$

$$\left(k-\omega^2 A\right)y_1-\eta\omega x_1-\omega^2 B\left(4\cdot\frac{1}{2}y_2\right)=0,$$

$$\left[k-\omega^2 A(4)\right]y_2-\eta\omega x_2-\omega^2 B\left(1\cdot\frac{1}{2}y_1+9\cdot\frac{1}{2}y_3\right)=0,$$

$$\left[k-\omega^2 A(9)\right]y_3-\eta\omega x_3-\omega^2 B\left(4\cdot\frac{1}{2}y_2+16\cdot\frac{1}{2}y_4\right)=0,$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$\left[k-\omega^2 A(n)^2\right]y_n-\eta\omega(n)x_n-\omega^2 B\left[(n-1)^2\cdot\frac{1}{2}y_{n-1}+(n+1)^2\cdot\frac{1}{2}y_{n+1}\right]=0. \qquad (41)$$

There is a simple solution of the system of equations (41) for absolute elastics(status $\eta = 0$) mountain rocks:

$$x_1=-\frac{2d}{B\omega^2},$$
$$x_2=\frac{\left(k-A\omega^2\right)x_1-c}{2B\omega^2},$$
$$x_3=\frac{2\left(k-4A\omega^2\right)}{9B\omega^2}x_2-\frac{1}{2}x_1, \qquad (42)$$
$$x_4=\frac{2\left(k-9A\omega^2\right)}{16B\omega^2}x_3-\frac{4}{16}x_2,$$
$$x_n=\frac{2\left[k-(n-1)^2 A\omega^2\right]}{n^2 B\omega^2}x_{n-1}-\left(\frac{n-2}{n}\right)x_{n-2},$$
$$n=5,6\ldots$$

In the end result (41) defines a reactive approach to solving the system.

It is also necessary that the deformation changes $n\to\infty$ – da $x_n\to\infty$ are stable. From the last (42) formula to paying for this condition

$$\left|\frac{2\left[k-(n-1)^2 A\omega^2\right]}{n^2 B\omega^2}\right|<1 \qquad (43)$$

anticipation of inequality is necessary and sufficient.

The latter is conditional, and this result can be used to solve technological issues.

Let's test the appropriateness of the mathematical dependence obtained on the following data. Assuming that mountain rocks are also composed of clay slag, the density of clay mortar is 190mm; pressure difference

We set the parameters at these prices.

(42) from the system of equations

$x_1=-0{,}365;$ $x_2=-4{,}330;$ $x_3=-20{,}403;$ $x_4=-48{,}000;$

$x_5=-55{,}819;$ $x_6\ldots x_{15}=4{,}064;$ $x_{25}=0{,}883;$ $x_{35}=-0{,}319.$

(38) can be written for stationary displacement changes (ie condition) by the expression of relative deformation.

$$\theta(t)=\sum_{n=1}^{\infty}x_n\cos n\omega t \qquad (44)$$

based on the formula. Table 1 presents the changes in relative relative deformation under the above conditions:

*Table 1:* Relative volume deformation

| $\omega t$ | 0 | $\frac{\pi}{30}$ | $\frac{2\pi}{30}$ | $\frac{3\pi}{30}$ | $\frac{4\pi}{30}$ | $\frac{5\pi}{30}$ | $\frac{6\pi}{30}$ | $\frac{7\pi}{30}$ | $\frac{8\pi}{30}$ | $\frac{9\pi}{30}$ | $\frac{\pi}{3}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\theta(t)$ | -124,997 | -102,447 | -83,893 | 11,214 | -0,032 | 0,000 | -0,032 | 11,214 | -83,893 | -102,447 | -124,997 |

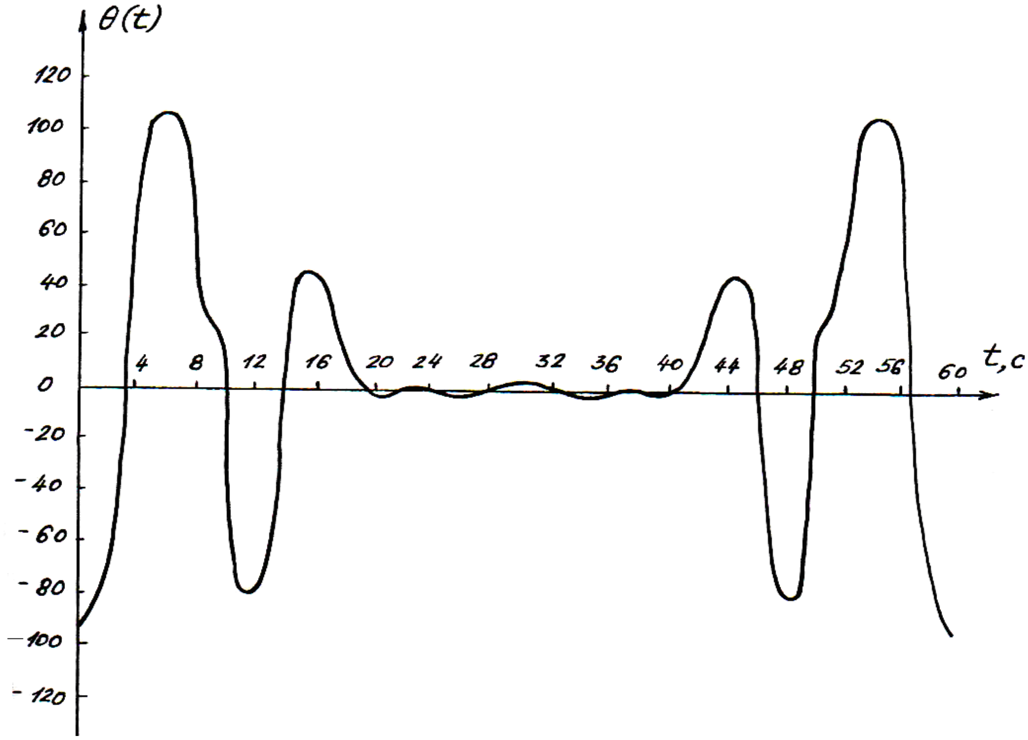


*Figure 1:* Relative deformation of anisotropic mountain rockregularity of amplitude change

The obtained results allow estimation of the velocity and amplitude characteristics of the well pressure change, which prevents the process of rock erosion (ie preventing the well wall from collapsing and collapsing on the wall itself).

## IV. Outcome and Suggestions

1. Thus, for the first time, the problem of dynamic instability of self-elastic rock rocks has been modeled and solved;
2. The conditions for the presence of stationary and non-stationary changes in the relative deformation of the self-elastic mountain rocks at periodic changes in the additional pressure in the population space;
3. A formula is proposed that allows the determination of the frequency and amplitude characteristics of the increase or decrease of deformation (for elastic rocks).

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