International Journal of Engineering & Technology, 7 (4.8) (2018) 312-317

International Journal of Engineering & Technology

Website:www.sciencepubco.com/index.php/IJET

Research paper

Stress-Strain Rock State Evaluation Method Around Deep Well

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Abstract

The analysis of the stress-strain state of deep wells in the rocks prone to the complications manifestation has been carried out. Engineering method proposed authors offer use in tactical decision making in designing and wells drilled. Stress-strain rock state evaluation of the borehole zone is performed, which is analyzed using data on the destruction of rock and reservoir pressure, measured in wells. The proposed evaluation method takes into account the relaxation of stresses in the zone near the well. The calculations were carried out outside the influence of a rock massif. Based on the calculations by the engineering method, it was discovered that intensive cavern formation with roughness and destruction would occur.

Keywords: *engineering method of calculation, stress-strain state, deep well, wellbore, complications..*

1. Introduction

Successful exploitation of oil and gas wells is largely determined by the efficiency of the wells construction. With the presence of growing depths and different geological conditions of drilling. We have a problem of providing stable wastewater. Consequently, the efficiency of drilling such wells depends on the condition and stability of their solid rock and the drilling zone. Providing long-term stability of rocks in these conditions is possible only with careful study and complex processes understanding.

These processes occur in rocks if the various combinations of stresses, the influence of mountain pressure are affected. Significant influence on the stability of the wellbore is the physical-chemical interaction of drilling fluids and rocks.

For example, in 2017, compared to 2016, JSC «Ukrgazvydobuvannya» increased the drilling volume by 25.4% [10]. This increased the complexity of work. Access to new areas of exploration and exploration with a more complex and inadequately explored geological structure should be consistent with drilling technology. In this case, it is necessary to predict the formation of collapses in the clay, but also carbonate and sandy rocks.

S. Lehnitsky and L. Makarov [2] solved the problems of the well state, but it was difficult to assess the stress-strain rock state by analytical equations. It is known that the problem of maintaining the stability of well walls becomes most relevant when drilling in clay rocks of varying degrees of litigation on oil and gas fields [2] but it was barely resolved. Also, the problem of assessing the stress-strain state was solved in certain private cases by A. Kalashnik N. Savchenko and others. The authors emphasize that the analysis of drilling wells in the area showed that most often complications arise due to violation of the well walls stability. For this reason, sometimes wells do not reach the design depths and are subject to liquidation, without having fulfilled their purpose at the expense of their construction.

Y. Baranovsky defined the energy balance components of a rock destruction process, which initiated the rock combined destruction during the deep well drilling. The efficiency of drilling a well depends on the ratio of the specific mechanical destructive energy and the specific potential change in volume [3, 4]. When analyzing the stress-strain state of an array that has not lost its stability, the mechanics methods of the deformation medium (theory of elasticity, plasticity, creep, etc.) are often used. [1, 11, 5]. The scientific fundamentals for the analysis of stress-strain rock state are contained in the works by O.Angelopoulou, B. Baidyuk, V.Voytenko, A. Gaivoronsky, V. Gorodnova, X. Feketa, B. Filatov, S. Khristianovich, R. Yaremiychuka, A. Papusha, V Stasenko, I. Fomenko and others [2, 8, 9]. Recently there has been an intense accumulation of information about the influence of various factors on the stress-strain state on the rocks around the well. There is an improvement in methods for studying the stress state of a well. [6, 7]. Methods of researching the stress-strain state, proposed by I. Fomenko [11], include a generalization of the mathematical modeling of a stress-strain state in anisotropic rocks. In general, for such calculations applied numerical methods, the elasticity theory, the boundary elements method with widespread use of PC [12]. Global tensions of the rock mass make significant changes in the distribution of local stresses near the vertical deepest well (about 8000 m). However, cases of such research for wells with a depth of 3000 – 4000 m are unknown. At the same time, the author proved that for the assessment of stress-strain state on the well wall it is enough to apply only one of the classic methods of calculation. Methods of studying stress-strain state of rocks around deep and shallow wells can be divided into analytical, numerical, for example ABAQUS [5], Methods of physical and mathematical modeling (Fig. 1).

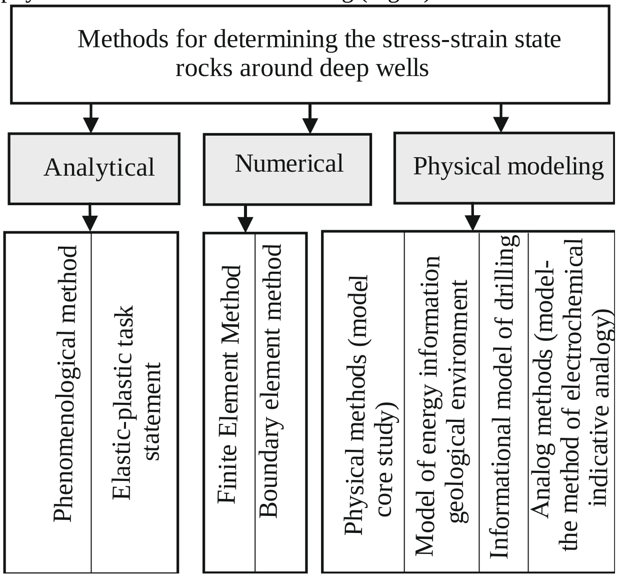

Fig. 1: Basic classification of methods for determining the stress-strain state of rocks around deep and shallow wells.

At present, numerical methods that are implemented in software systems are being used , but calculations with the help of software complexes require especially powerful computer systems as well as relevant specialists and time expenditures, which is not always possible in minor oil and gas enterprises of Ukraine. Therefore, it is especially important to develop an engineering methodology that would allow estimating the stress-strain state of the well with less economic costs and time expenditures.

2. Methodology and research

The reliability of analytical calculations is determined by the correspondence of the mathematical model to the real state. The accuracy of the calculation depends on the exact determination of the rock mechanical properties. The most common are engineering methods of calculation due to the efficiency of stresses and displacements calculations (efficiency of data interpretation) and the ease of its implementation,. They are the most difficult in their development due to the need to achieve these advantages and adhere a sufficient accuracy of received calculations.

Analysis of drilling of wells in areas has shown that complications are most often due to instability of borehole. For this reason, sometimes wells do not reach the design depths and are subject to liquidation, not fulfilling their purpose at the expense of their construction of large funds. Rock near the wells are subjected to three basic pressures: gravity P_g, lateral geostatic P_2, and P_1 counter pressure. Pressure of the massif from the wellbore consists of the hydrostatic pressure of the pile of the drilling mud and the hydrodynamic pressure due to the conduction of technological processes in the well.

The authors proposed an engineering method for calculating the stress-strain state of the wellbore. This method allows the engineer in the process of drilling wells to analyze the state of the well and make operational decisions to prevent emergencies in the well. The method does not require the use of additional software and includes a set of certain mathematical operations, which distinguishes it from the others.

We solved the problem in the following setting: the stressed state of a heavy isotropic, homogeneous elastic-plastic array was studied near the vertical circular cylindrical development of the finite depth made in this area . The elementary section (element)

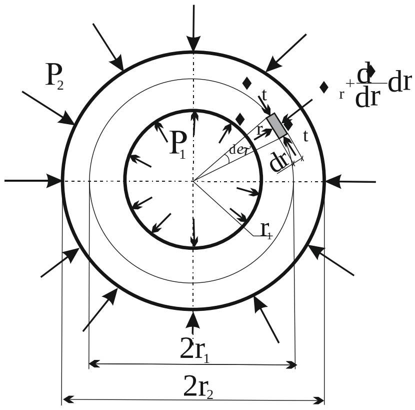

Fig. 2: Tension in the explored element of a deep well

of a deep well, as an element with a hole of a constant section with radius r_1 loaded with internal pressure P_1, constant thickness and an external radius r_2 loaded with external pressure P_2, was investigated. In the process of solving a mathematical model was compiled, which includes the balance equation; the correlation between the components of the deformations and displacements; equations describing the properties of the medium; stress intensity and strain intensity; and also boundary conditions $\sigma_r = P_1$. On the boundary between elastic and plastic deformations, the tensile and strain values are consistent $\sigma_r^{pl} = \sigma_r^{el}$, $\sigma_t^{pl} = \sigma_t^{el}$, $u^{pl} = u^{el}$, $\sigma_t^{pl}+\sigma_r^{pl}= \sigma_t^{el} + \sigma_r^{el}$, where σ_r^{pl}, σ_r^{el} – radial stresses in the plastic and elastic region, σ_t^{pl}, σ_t^{el} – tangential stresses in the plastic region; u^{pl}, u^{el} – radial movements in the plastic and elastic region.

The basis of the calculation is the assumption that the load is evenly distributed along the thickness of the element and the absence of loads in planes parallel to the longitudinal axis of the element. The problem is asymmetry, because then the possibility of destruction increases. Deformation movements in the considered half-space from the vertical cylindrical wellbore occur only in planes passing through the axis of symmetry. In all such planes the distribution of deformations and stresses will be the same. It follows from the assumptions that all points of an element are in two axes tense. This allows us to reduce the solution of the volumetric problem to the solution of the distribution of deformations and stresses in one plane passing through the axis of symmetry of the well (to a flat deformed state). The assumption is valid if $r_2/t \geq 2$ (where t – the thickness of the element – the deformed part of the array). In connection with the features of the problem, where an elastic-plastic array is considered, plastic, elastic plastic and elastic deformation may occur in the borehole zone of the well. Therefore, we investigate the plastic and well elastic zones. The values of stresses in which plastic deformations appear on the inner surfaces of the workings are based on the Mises' plasticity condition:

$$(\sigma_r-\sigma_z)^2+(\sigma_t-\sigma_z)^2+(\sigma_r-\sigma_t)^2=2\sigma_{fl}^2. \quad (1)$$

Whereas in this element the normal stresses σ_z are not considered (they are taken uniformly distributed throughout the array), then the equation can be represented as (the equivalent stress on the energy hypothesis of plastic deformation):

$$\sigma_t^2-\sigma_t\sigma_r+\sigma_r^2=\sigma_{fl}^2, \quad (2)$$

where σ_{fl} – the fluidity of the material of the well element at a given depth. Apply the dimensionless values of the radius:

$$q=\frac{r}{r_1};\quad \beta=\frac{r_c}{r_1};\quad \alpha=\frac{r_2}{r_1}.$$

Plastic area:

$$\sigma_t = \frac{2}{\sqrt{3}}\sigma_{fl}\cos(\varphi - \frac{\pi}{6}), \sigma_r = \frac{2}{\sqrt{3}}\sigma_{fl}\cos(\varphi + \frac{\pi}{6}).$$

(3)

Elastic area:

$$\sigma_t = \sigma_{fl}(\cos\varphi_c + \frac{\beta^2}{\sqrt{3}}\cdot\frac{\sin\varphi_c}{q^2}); \sigma_r = \sigma_{fl}(\cos\varphi_c - \frac{\beta^2}{\sqrt{3}}\cdot\frac{\sin\varphi_c}{q^2}); \quad (4)$$

The function φ is related to the dimensionless radius' of the following relations:

$$q = e^{\frac{\sqrt{3}}{2}(\varphi_1 - \varphi)}\sqrt{\frac{\sin\varphi_1}{\sin\varphi}} \quad (5)$$

$$\beta = e^{\frac{\sqrt{3}}{2}(\varphi_1 - \varphi_c)}\sqrt{\frac{\sin\varphi_1}{\sin\varphi_c}} \quad (6)$$

where: φ_1 – value of the function φ on the inner surface with radius r on the walls of the wellbore; φ_c is the value of the function φ at the boundary of the elastic and plastic regions in the depth of the wellbore massif. The values of φ_1 and φ_c are determined from the equations:

$$-\frac{P_1}{\sigma_{fl}} = \frac{2}{\sqrt{3}}\cos(\varphi_1 + \frac{\pi}{6}); -\frac{P_2}{\sigma_{fl}} = \cos\varphi_c - \frac{e^{\sqrt{3}(\varphi_1 - \varphi_2)}}{a^2\sqrt{3}}\sin\varphi_1 \quad (7)$$

For the consideration of radial deformations ε_r that arise in a rock mass during drilling, we use the relations in which the circumferential ε_t and the radial deformations ε_r are represented as functions of the radial displacement *u*:

$$\varepsilon_t = \frac{u}{r}; \varepsilon_r = \frac{du}{dr} \quad (8)$$

The connection between stresses and deformations in a two-axial stressed state within the limits of elasticity will be:

$$\varepsilon_t = \frac{1}{E}(\sigma_t - \mu\sigma_r); \varepsilon_r = \frac{1}{E}(\sigma_r - \mu\sigma_t), \quad (9)$$

where E is the elastic modulus of the rocks; μ is the Poisson coefficient. Outside the elasticity, this connection is represented by dependencies:

$$\varepsilon_t - \varepsilon_0 = \frac{\varepsilon_i}{2\sigma_i}(2\sigma_t - \sigma_r); \varepsilon_r - \varepsilon_0 = \frac{\varepsilon_i}{2\sigma_i}(2\sigma_r - \sigma_t), \quad (10)$$

where ε0 – mean linear deformation:

$$\varepsilon_0 = \frac{\sigma_0}{2K}, \quad (11)$$

σ0 – mean normal tension:

$$\sigma_0 = \frac{(\sigma_t + \sigma_r)}{3}, \quad (12)$$

K – volume of the elastic modulus:

$$K = E[3(1-2\mu)]^{-1}, \quad (13)$$

From relations, the dependence for determining the radial displacement in an elastic region during elastic-plastic deformation of rocks will be:

$$u = \frac{r_1\sigma_{fl}}{E}[(1-\mu)\cos\varphi_c + (1+\mu)\frac{\beta^2\sin\varphi_c}{q^2\sqrt{3}}]q \quad (16)$$

For radial displacements in the plastic region under elastic-plastic deformation, we will use the above-mentioned dependencies, which implies that

$$\frac{\varepsilon_r - \varepsilon_0}{\varepsilon_t - \varepsilon_0} = \frac{2\sigma_r - \sigma_i}{2\sigma_t - \sigma_r}, \quad (17)$$

or:

σ_i – intensity of stresses:

$$\sigma_i = \sqrt{\sigma_t^2 - \sigma_t\sigma_r + \sigma_r^2}, \quad (14)$$

ε_i – intensity of deformations:

$$\varepsilon_i = \frac{2}{\sqrt{3}}\sqrt{\varepsilon_t^2 + \varepsilon_t\varepsilon_r + \varepsilon_r^2}. \quad (15)$$

$$\frac{du}{dq} = \frac{r_1}{9K}(\sigma_t + \sigma_r) + \frac{2\sigma_r - \sigma_t}{2\sigma_t - \sigma_r}\cdot\frac{u}{q} - \frac{r_1}{9K}(\sigma_t + \sigma_r)\frac{2\sigma_r - \sigma_i}{2\sigma_t - \sigma_r} \quad (17)$$

Substituting in the obtained equation instead of the circular and radial stresses, we obtain the differential equation for radial displacement in the plastic region:

$$\frac{du}{dq} - \frac{1-\sqrt{3}tg\varphi u}{1+\sqrt{3}tg\varphi q} - \frac{4\sqrt{3}r_1\sigma_{fl}}{9K}\frac{\sin\varphi}{1+\sqrt{3}tg\varphi} = 0 \quad (18)$$

The integral of this equation:

$$u = e^{\int\frac{(1-\sqrt{3}\,tg\varphi)dq}{(1+\sqrt{3}\,tg\varphi)q}}[C + \int\frac{4\sqrt{3}r_1\sigma_{fl}}{9K}\frac{\sin\varphi}{1+\sqrt{3}tg\varphi}e^{\frac{(1-\sqrt{3}\,tg\varphi)dq}{(1+\sqrt{3}\,tg\varphi)q}}dq] \quad (19)$$

Substituting *φ* for *q* instead of *q* and making the transformation we obtain:

$$u = \frac{e^{\frac{\sqrt{3}}{2}\varphi}}{\sqrt{\sin\varphi}}[C - \frac{\sqrt{3}\sigma_T r_1 e^{\frac{\sqrt{3}}{2}\varphi_1}\sqrt{\sin\varphi_1}}{9K}\cdot\frac{\sin\varphi - \sqrt{3}\cos\varphi}{2e^{\sqrt{3}\varphi}}] \quad (20)$$

Constant integration of C is obtained under the condition of continuity of the radial displacement on the boundary with elastic and plastic regions, that is, at:*q=β; φ=φc*

Equating the above expressions, we obtain:

$$C = \frac{r_1\sigma_{fl}\beta\sqrt{\sin\varphi_c}}{Ee^{\frac{\sqrt{3}}{2}\varphi_c}}[(1-\mu)\cos\varphi_c + (1+\mu)\frac{\sin\varphi_c}{\sqrt{3}}]\times$$

$$\times\frac{\sqrt{3}\sigma_{fl}r_1 e\frac{\sqrt{3}}{2}\varphi_c\sqrt{\sin\varphi_1}}{18Ke^{\sqrt{3}\varphi_c}}(\sin\varphi_c - \sqrt{3}\cos\varphi_c) \quad (21)$$

Finally, the formula for finding the values of radial displacements in the plastic region will have the form:

$$u=\frac{\sigma_{fl} r_1 e^{\frac{\sqrt{3}}{2}\varphi}}{\sqrt{\sin\varphi}}\left\{\frac{2\beta\sqrt{\sin\varphi_c}}{\sqrt{3}Ee^{\frac{\sqrt{3}}{2}\varphi_c}}[\cos(\varphi_c-\frac{\pi}{6})-\mu\cos(\varphi_c+\frac{\pi}{6})]+\right.$$
$$\left.+\frac{\sqrt{3}e^{\frac{\sqrt{3}}{2}\varphi_1}\sqrt{\sin\varphi_1}}{9K}[\frac{\cos(\varphi+\frac{\pi}{6})}{e^{\sqrt{3}\varphi}}-\frac{\cos(\varphi_c+\frac{\pi}{6})}{e^{\sqrt{3}\varphi_c}}]\right\} \quad (22)$$

Comparing the deduced calculation dependences it can be noted that consideration of additional conditions complicating the mathematical model of the process leads to a significant complication of the equations calculation. At the same time, they do not mak**e** large changes in the values of calculated variables. There is a simple refinement of values. Therefore, in this case, it is unlikely that it would be advisable to complicate the method of calculation, which aims to engineer the evaluation of the stress-strain state of the array weakened by a vertical well. The engineering method should be simple, labor-saving, clear and very reliable.

The analysis of the stress-strain state of the massif, weakened by a deep well, in this case is carried out on the example of the well of Borisov Square (Russia) in relation to the zone with intense cavern formation in sandstones in the interval at a depth of 4065 – 4260 m.

The diameter of the drill hole is 215.9 mm, the depth of the well is 4065 m, the density of the rocks γ_r = 2.33 g/cm^3. The elastic modulus of the rocks $E = 3\cdot 10^4$ MPa, the drilling mud density used for the removal of the drill bit from the well, γ_s = 1.63 g/cm^3. The pressure of the hydraulic fracture of the formation is conventionally taken 70 MPa, the permissible margin of rock strength in the conditions of occurrence is assumed to be equal to σ_{fl} = (0.85 – 0.9) P_{gr} = 57.5MPa, hydrostatic pressure at a depth of 4065 m taken 66.3 MPa, P_2 = 52.6 MPa, P_{pl} = 40.7 MPa. In this case, the problem is considered as an inverse.

The conducted analysis of the state of rocks (Table 1, 2, 3) shows that in a rock mass that is not in equilibrium, forces of considerable magnitude are capable of not only breaking or destroying the rocks forming the walls of the well, but also destroying the artificial constructions intended for their fastening. At a depth of 4065 m, according to the calculation results, σ_r and σt are only compressive stresses, σ_i are tensile maximum stresses with values of 53.8 MPa. There is a deformation of the rock.

In the horizontal plane (when passing the array) near the borehole of the well all tensions change their magnitude. At the boundary of the array, represented by a surface with radius r_1 and r_2, only compressive normal stresses are valid. Here σ_z and σr intensively increase and at level $r = r_2$, reach their limit values. At this section, the voltage σ_t with a large gradient decreases, the sign changes to the opposite and again with a large gradient begins to increase. At the boundary, where $r = r_2$ of the stress σ_t have a negative value, (σ_t = -14.7 MPa). The stress σ_i, with approximately the same intensity as σ_t without jumps and fluctuations, is sharply reduced. Further removal from the wellbore through the intersection of the array indicates that all the stresses are directed to their constant values, of which only σ_z and σ_0 exceed σ_{fl} of the rock.

Table 1: Characteristics of a tense state of rocks in the well at a depth of 4065 m at P_1 = 66.3 MPa

Investigated surface with radius	Existing stresses, MPa					Values accepted for calculation, MPa
	Radial	Circular	Vertical	Normal	Octahedric	
r_1	-66.3	-29.5	-88.8	39.3	-63.1	P_1 = 66.3 MПa
r_c	-60.6	-13.4	-93.5	53.8	-53.8	P_2=52.6 MПa
r_2	-52.4	-14.7	-93.5	48.3	-55.5	σ_{fl} = 57.5 MПa
1,5r_1	-56.2	-40.0	-93.5	39.6	-63.3	
2r_1	-52.6	-43.5	-93.5	39.0	-63.2	

The values of stress outside the well zone impact on an array of rocks are: σ_r = -52,6 MPa; σ_z = -93,5 MPa; σ_t = -43,5 MPa; σ_i = 39 MPa and σ_0 = -63,2 MPa. Here, the rocks are in a state of stable equilibrium, close to the state of comprehensive compression, and, the value of the existing stresses determined by this state, also exceeds the value of the yield strength of the rocks, but below their hydraulic fracture. That is, breeds in an unbroken array are in a state of elastic - plastic deformation. The instantaneous radial displacement of the loaded rock enclosed in the zone of influence of the well on the array and the prone elastic-plastic deformations, make 1,5 – 1,3 mm.

As a result, the calculated stress state of rocks along the walls and near the wells shows intense cavern formation with peeling of rocks and aspirations. Wells have cracking and cavities, which fragile destruction are prone to. The rooting of rocks is determined by the maximum intensity of normal stress σ_i = 53,8 MPa and its zone of action, which is only $r = 1{,}15r_1$, cavern formation and is the result of a general stressed state of rocks, but the defining here will be normal tangential stress σ_t. Maximum value is-43.5 MPa. To obtain a stable state of the barrel walls at elastic deformation of rocks and for the complete elimination of tensile stresses and bending points, it is necessary to create a back pressure in the well, equivalent to a density of the drilling mud 1,6 g/cm^3.

In the section at the depth of 4080 m, the radial, vertical, octahedral stresses are only compressive, the circular stresses vary, with stretching from 38,4 MPa to the compressive 16,2 MPa σ_i – the stretching maximum value of 69,2 MPa, there are plastic, elastic-plastic deformations rocks). The rocks at a depth of 4080 m are represented by unevenly silty, clay limestone . In some areas, the siltstone is sandy.

Table 2: Characteristics of the stress state of rocks in the well at a depth of 4080 m at P_1 = 66.9 MPa

Investigated surface with radius	Existing stresses, MPa					Values accepted for calculation, MPa
	Radial	Circular	Vertical	Normal	Octahedric	
r_1	-66.9	16.2	-89.8	60.4	-53.0	P_1 = 66.9 MПa
r_c	-57.0	14.0	-93.8	69.2	-44.6	P_2=46.2MПa
r_2	-54.7	10.2	-99.8	58.4	-49.2	σ_{fl} = 67.5 MПa
1,5r_1	-51.5	-27.1	-93.8	41.4	-57.5	
2r_1	-46.7	-38.4	-93.8	39.5	-57.5	

Table 3: Characteristics of the stress state of rocks in the well at a depth of 4260 m at P_1 = 69 MPa

Investigated surface with radius	Existing stresses, MPa					Values accepted for calculation, MPa
	Radial	Circular	Vertical	Normal	Octahedric	
r_1	-69.0	47.6	-93.8	62.4	-52.5	P_1 = 69 MПa
r_c	-55.3	23.4	-94.9	75.4	-43.3	P_2=55.1 MПa
r_2	-54.7	18.5	-94.9	74.9	-43.3	σ_{fl} = 57.5 MПa
1,5r_1	-53.1	-45.8	-94.9	34.1	-66.3	
2r_1	-69.0	47.6	-93.8	62.4	-52.5	

In this zone, that is, with allowable values of rocks, it changes dramatically, and the rocks move from the field of plastic deformation to the area of action of only elastic-plastic deformations, but with a complex stressed state. The area of elastic deformations extends to the surface with r = 1,5r_1 (r_1- radius of the well).

At a depth of 4260 m in the well in Borisov area there are thin layers of siltstone, argillites, sandstones. On the walls of the well and near them to the zone with $r = r_c$ (r_c – current radius of the zone), there is a stressful state in the rock formations causing plastic deformations in the rocks.

It was established that during loading of rocks and endurance under loading for about 8 – 10 hours there is a certain change in the stress state of the rock – there is a relaxation of stresses. The next process is stabilized and the stress-strain state of the rocks remains practically unchanged. The most intense reduction of stresses is observed in the peritoneal zone and in the initial period after loading. Analysis of the values of relaxed and calculated stresses showed a decrease in their time by 5 – 15%, while in clay rocks about 10 – 15%. The effect of relaxation can be taken into account by the introduction of correction coefficients K_p and K_m, which take into account the relaxation of stresses in the borehole zone and beyond the influence of the well on an array of rock (K_p = 0.9 – 0.85; K_m = 0.9 – 0.95).

When quantifying the existing voltages in the rocks need to consider another condition. In rock formations, in conditions of its natural occurrence, the properties of the rock, as well as the value of its mechanical characteristics, change over time. Experimental-theoretical studies have established the reduction of permissible values of stresses. Their change according to the law of long durability of rocks, which in the wells is 0.85 – 0.95 from the original [2].

Taking into account the above two features in the behavior of rocks in the conditions of their occurrence, it can be admitted that when drilling wells, the stress state of the rocks changes with time in proportion to changes in the strength of rocks on the condition of their long durability. In other words, reducing the strength of rocks in the well according to the law of long durability is offset by the relaxation of existing stresses. Consequently, in the relative form of the instantaneous value (in the calculation of accepted characteristics of the rocks by values σ_{fl}) and the ratio of existing stresses, taking into account the long-term strength, will be approximately the same - about 1. Therefore, the quantitative assessment of the stress state of rocks on the trunk and near the wellbore can be carried out using the proposed method [5] with an accuracy that is sufficient for engineering practice,.

In the explored well, intense formation of cavities with peeling of rocks and stones should occur, based on the obtained stress state of rocks along the walls and near the walls of the well, . Wells will have shredding and cavities, typical for fragile destruction. Rooting of rocks is determined by the magnitude and area of maximum stresses σ_i, whose zone of action is $r = 1{,}5r_1$. Creation of caverns and cracks will be a consequence of the general tense state of rocks, but what will be defining here is the normal tensions. Interpretation of these conditions makes it possible to assess the stability of the walls of the borehole and allows to set the required value for counter pressure in the well. It is taken into account that the value of the counterweight, corresponding to the optimum conditions of drilling in the range of rocks, should not cause complications during drilling. In this regard, the analysis of permissible values makes it possible to change the parameters of the drilling mud or its type in a scientifically well-grounded way, as well as change the design of the well in particularly difficult geological conditions. The results of the calculations were compared with the results of field studies in well drilling. At the depths of the wells that were analyzed there were cracks and fractures

3.Conclusions

The recommended method of calculation allows to perform an assessment of the stress-strain state of the trunk of a deep well on a sufficiently (for engineering practice) scientific basis and to formulate, in particular, requirements for its stability. The effect of relaxation is taken into account by the introduction of correction coefficients, which take into account the stress relaxation in the borehole zone and the boundary of the well effect on an array of rocks. It is established that cavern formation and scaling, in turn, is a consequence of the general stressed state of rocks, but determining their origin and development will be σ_t.

The advantage of the proposed method is the fact that there is no need in expensive, state-of the-art computer equipment. The method allows evaluating quickly the state of the wellbore during drilling and reacting rapidly to the problems that arise during well drilling. The given stress state of rocks is not preferable in terms of the stability of the walls of the wellbore. Using an example of a Borisov square borehole, an application of the engineering express method is shown and it is established that under the action of σ_t and bending moment there will be variously directed cracks both along the walls of the well and there will be rock breaks. The zone, which is under the influence of rock pressure of a rock mass, which is in a plastic state under conditions close to all-round compression, will contribute to the further development of caverns in the size of two wells. This is confirmed by the practice of well drilling.

Acknowledgement

The authors thank the doctor of technical sciences Blokhin V.S. for technical assistance in conducting research.

References

[1] Alimdzhanov M.T. Spatial axially symmetric stability of a vertical well in an array containing a layer with reduced strength properties // The Oil and Gas Business, Network Edition. No.2, (2008), pp. 1 http://ogbus.ru/article/view/prostranstvennaya-osesimmetrichnaya-ustojchivost-vertikalnoj-skvazhiny-v-massive-soderzhashhem-sloj-s-ponizhennymi-prochnostnymi-svojstvami last visit:20.09.2018.

[2] Bandurina O.V. Current state of the problem of analysis of the stress-deformed state of rocks around deep wells// Collection of scientific works (branch engineering, construction), Poltava: PoltNTU, Vol.36, No.1, (2013), pp:373-383.

[3] Baranovsky E.M., Moisyshyn V.M. The main task of geomechanics in solving deep drilling problems // Exploration and development of oil. and gas. deposits, No.4, (2006), pp:5-9.

[4] Baranovsky E.M., Moisyshyn V.M. Combined destruction of rocks during drilling of deep wells // Scientific. Visn Ivano-Frankivsk nats tech Un-oil and gas, No.1, (2006), pp:26-30.

[5] Gaede O., Karrech A., Regenauer-Lieb K. Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis // Geophysical Journal International, Vol.193, No.3, (2013), pp: 1095-1109. https: //academic.oup.com/gji/article/193/3/1095/6041126. last visit:20.09.2018.

[6] Karnev V.I., Kovalenko Yu.F. Geomechanics of oil and gas wells // The Vestnik of the Nizhny Novgorod Univ N.I. Lobachevsky, Vol.2, No.4, (2011), pp: 448-450.

[7] Karnev V.I. Influence of the stress-strain state of rocks on the filtration process, and the flow rate of wells: author's abstract. dis to acquire a scholar. Degrees of the doctor of technical sciences 01.02.04 - mechanics of a deformable solid. St. Petersburg, (2010), 34 p.

[8] Papusha A.N., Gontarev D.P. On the issue of calculating the strained-deformed state of a rock massif in the vicinity of a super-deep vertical well // Vesnyk MGTU, No.5, (2010), pp: 81-93.

[9] Stasenko V.M., Karpenko V.M., Kozachenko M.I. Problems of estimation and forecasting of geobaric and stress-deformed state of a rock mass during drilling of deep oil and gas wells // Oil and gas industry, No.2, (2008), pp: 20-22.

[10] Ukrgazvydobuvannya increased the production of gas at 513 million cubic meters // Our oil and gas. Corporate Edition, No.1, (2017), pp: 2-3.

[11] Fomenko I.K. Mathematical modeling of the stress state of the engineering-geological massif, folded by anisotropic rocks: on the example of the prosthetic massif of the Kola super-deep well: author's abstract. dis to acquire scientific degree of candidate of geological-mineralogical sciences according to the specialty 25.00.08 ”Engineering geology, permafrost and soil science”, Moscow, (2001), 139 p.

[12] Xia-Ting Feng ”New rock mechanics developments in China”,12th ISRM International Congress on Rock Engineering and the

Environment in 2012, Qian&Zhou, (2012) pp.71-79 https://books.google.com/ last visit:20.09.2018.

[13] Zotsenko, M., Vynnykov, Y., Doubrovsky, M., Oganesyan, V., Shokarev, V., Syedin, V., Meshcheryakov, G. (2013). Innovative solutions in the field of geotechnical construction and coastal geotechnical engineering under difficult engineering-geological conditions of ukraine. Paper presented at the *18th International Conference on Soil Mechanics and Geotechnical Engineering: Challenges and Innovations in Geotechnics, ICSMGE 2013, , 3*2645-2648.