UDC 622.245

Investigation of strain-stress state round the borehole massif containing the plastic rocks

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Abstract
The experimental researches of rocks properties change depending on pressure in the borehole and in the massif of tight stratum at different distance from a borehole in course of time are conducted. Influence of temperature stresses on plastic rocks destruction in the massif when drilling was analyzed.
Key words: STRAIN-STRESS STATE, RHEOLOGICAL PROPERTIES, BOREHOLE, BORE, PLASTIC ROCK

Statement of a problem in general terms and its connection with important practical tasks. The forecasting of tension in the bore of vertical deep borehole and nearby is of the great practical value. The majority of complications, which can be seen in the boreholes for today, are result of stress state of the massif including its internal processes, in particular, droops, which are caused by deep drilling in the borehole. And until this stress state is established and evaluated, its nature and mechanism are discovered, it is difficult to take scientifically based measures aimed at protection from these complications, and their prevention, which is most significantly [1, 2].

The analysis of the last researches and publications, on which the solution is based. The investigation of change of three-dimensionally stressed state of a massif containing plastic rocks is important both at a stage of borehole drilling and at a stage of their lining and operation. The problem of change of rocks stress state when opening of a massif and after its lining remains underexplored till this time due to complexity of technical solution of the problem of pressure direct measurement in the massif. The papers of I.K. Fomenko, A.M. Papusha, E. M. Baranovs'kiy [1-5] are devoted to the solution of this problem to a greater or lesser degree. The task of bores strain-stress state evaluation was difficult to describe by the analytical equations.

Emphasizing of the shared problem parts, which were not solved earlier and to which this article is devoted. The rocks are often destructed outside the area of elastic deformations – in the area of plastic state, which is characterized by the considerable permanent deformation in rocks. Plastic deformations result from dislocations displacement; they begin from areas of a crystal structural imperfection and are spread over the slip plane successively, without disrupture of crystal structure and substance integrity. At the same time in rocks, we can observe the relative motion of substantial volumes, reduction, mashing and so on (quasiplasticity). It is possible to describe a massif behavior under the influence of forces by different models: mechanical model, which is a spring (Hooke body); mechanical model, which is a heavy body, lies on the horizontal plane and is connected to a spring (Saint-Venant body). The majority of rocks belong to the strengthened bodies, and it is necessary to increase stress in order to support the plastic deformations in them; thus the stresses increase with the speed reduction. Such rock behavior is modelled by a combination of perfect elastic Hooke body and perfect viscous Newton body (piston with the holes that moves in the cylinder, which is filled with viscous liquid). The Kelvin-Voigt body model takes place at parallel connection of these bodies, and Maxwell body – at series connection. However, these models describe the strain-stress state of rocks without considering of the rheological properties of rock and corresponding thermobaric conditions of massif.

Therefore, the **purpose** of work is conduction of experimental researches of rocks properties change depending on pressure in the borehole and in the massif of tight stratum at different distance from a borehole in course of time.

Statement of the main material of researches.

The hard rocks plasticity increases with temperature and lateral thrust growth; however, the quantity of dislocations in rocks is not changed, but their mobility, which is conductive to plastic deformation, increases considerably. The rocks, which behave as brittle under normal conditions, obtain the explicit plastic properties at elevated pressures and temperatures. It is important when deposits developing at great depths. For example, the limestones and aleurolite ability to plastic deformations appears with confining pressure of about 50 MPa, the anhydrite one appears at about 100 MPa. Plastic deformations with considerable lateral thrust are explained by the fact that under these conditions, the internal movements and shifts, which do not lead to integrity damage and cracks emergence (that is to destructive deformations), can be developed more easily.

The massif behavior with high-plasticity rocks contents on model is investigated. The paraffin wax, which was limited horizontally by a pipe of big diameter and vertically by rigid plates, was used as model of the massif of high-plasticity rock. The rubber tube filled with liquid was used as the model of borehole. Pressure upon fluid layer model was produced by a hydraulic press, which maintained the set pressure automatically during the whole experiment. The semiconductor sensors of volumetric pressure, which were installed at different distance from a borehole axis, were used in order to measure the pressure in the model of borehole and massif. Prior to the experiment, the massif model with a relative borehole was maintained up to pressure balance in all the volume points. Then the pressure in the borehole model was reduced to atmospheric, and the borehole was pressurized. Indications of pressure sensors were registered during the entire experiment by automatic recorders. In Fig. 1, the diagrams of pressure change in borehole and in massif of tight stratum in pressure-time coordinates at different distance from a borehole axis are shown.

From Fig. 1, it can be seen that the pressure is reduced along the entire massif area if the pressure in the borehole model decreases (it corresponds to opening moment of the plastic rocks massif by the borehole). At that, the pressure drop value in the massif decreases when point distancing from a borehole axis [6].

After borehole killing, the pressure change nature in the massif at different distance from the borehole axis differs considerably. If the pressure remains invariable in a borehole and at distance of two radiuses of a borehole, we can observe its stabilization and some reduction, and then decrease at distance of five radiuses; at distance of more than 8R from the borehole axis, the pressure increases, and at distance of more than 11R, it exceeds the set pressure. In course of time, the set dynamics changes: pressure starts falling on peripheral sensors and increasing in the borehole and bore zone. In Fig. 2, the diagram of pressure change in borehole and in massif of tight stratum in coordinates pressure-distance from a borehole axis after borehole pressurization, which corresponds to the massif condition after borehole casing, is shown.

From Fig. 2, it can be seen that in this experiment, the maximum pressure changes in the massif of tight stratum take place at distance from a borehole axis to borehole eight radiuses and from eight to eleven radiuses to the periphery. In a zone, pressure changes are insignificant from eight to eleven radiuses of a borehole.

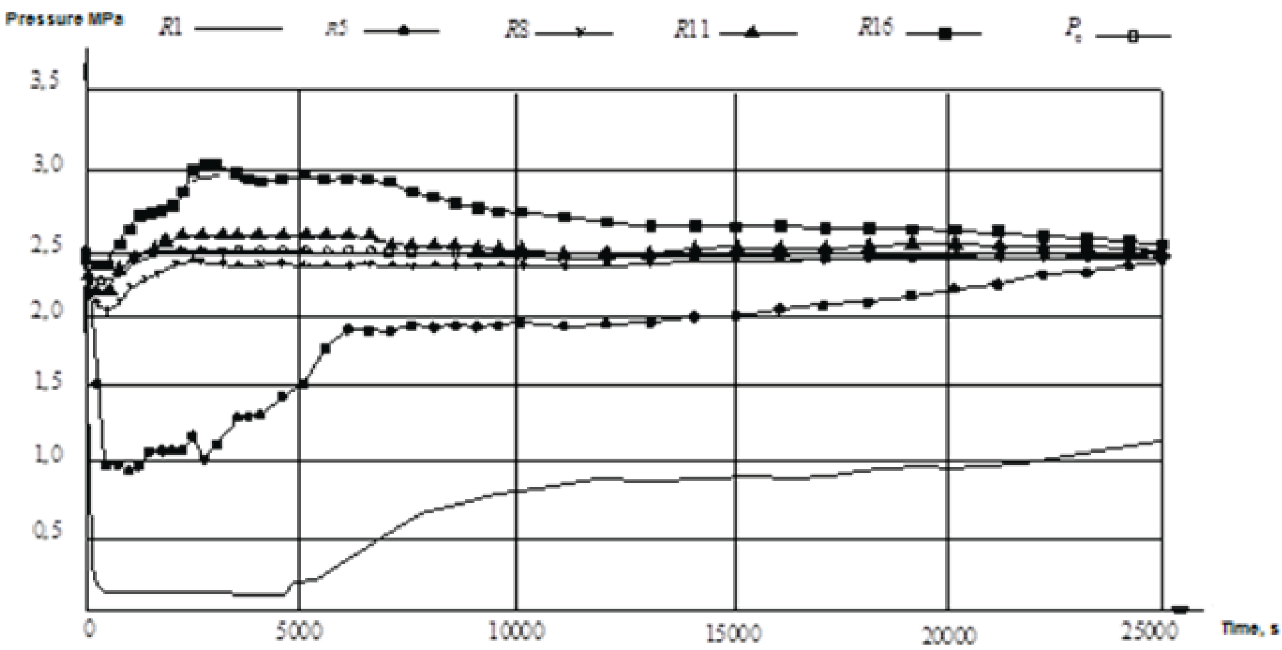

Figure 1. Diagrams of pressure change in borehole model and at different distances from an axis (R1-R16) of the borehole in the model of tight stratum after pressure reduction in a borehole to atmospheric and its pressurization depending on holding time. P_0 - initial pressure at model, MPa, R - borehole radius.

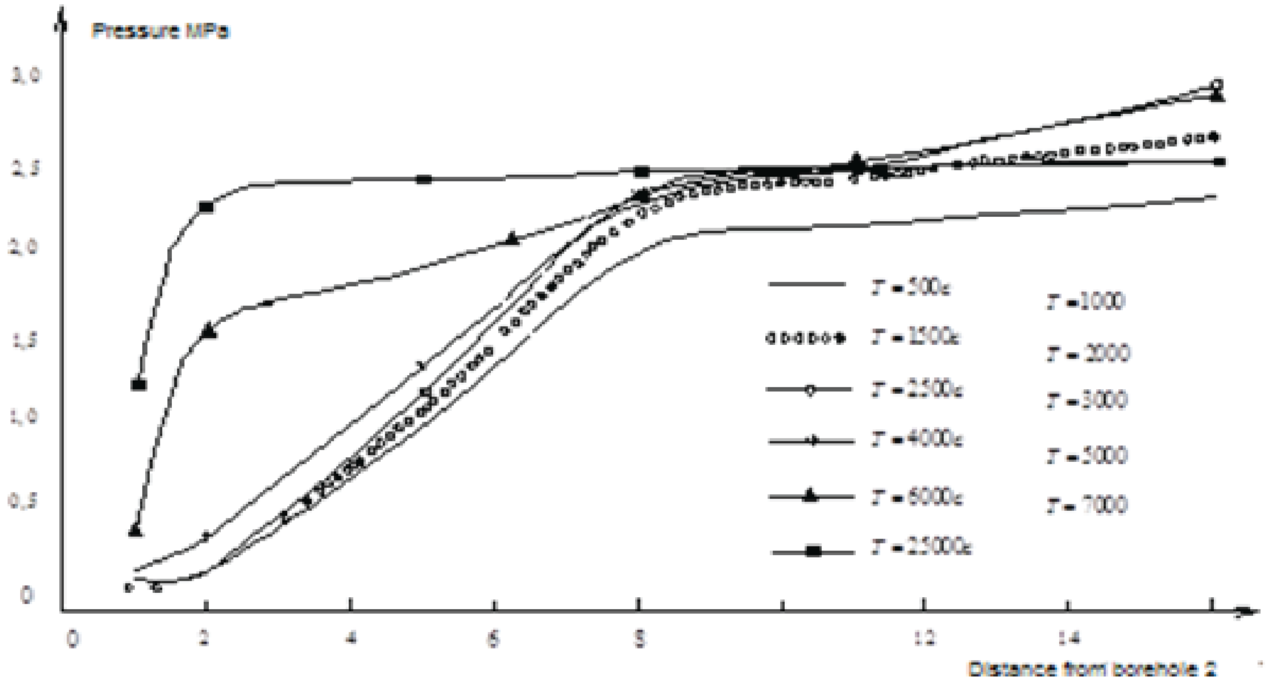

Figure 2. The diagram of pressure change in a borehole model and tight stratum in different periods after borehole pressurization depending on sensor distance from a borehole axis

The analysis of diagrams shows that pressure changes in the massif of tight stratum model is of impulse nature. It is evident that such character is predetermined by energy periodic accumulation in a certain zone of the massif, and consequently, its shift towards a borehole [6].

When evaluating of strain-stress state of plastic rocks round a borehole, it is necessary to consider the thermal conditions of their bedding. Complexity of an evaluation of rocks resistance to thermal influence round a bore is, first of all, that this resistance depends on coefficient of linear heat expansion of material, its modulus of elasticity, thermal conductivity, and also regularity of temperature field distribution, a surface condition, properties of surrounding field and so forth.

For example, if the body is heated unevenly, the individual elements deformations, which correspond to such heating, become limited; inasmuch as free deformations are disturbed by the neighboring elements. Thus, there will be stresses, which distribution will depend on temperature distribution regularity.

If material is uniform, and temperature throughout the body is identical, the temperature deformations in a body are limited to nothing and do not cause the temperature stress. The temperature stresses can emerge only in the case when the material is nonhomogeneous according to the temperature coefficients of volume expansion or due to irregular distribution of temperature field throughout the volume, and also under the condition of external limiting of temperature deformations on a body surface. Therefore, temperature stress is always set by temperature deformation; so irregular temperature fields, unlike the uniform ones, can be followed by change of temperature stress.

It is evident that there is always volumetric temperature stress even at uniform temperature fields in rocks layers, as rocks most often consist of the coherent minerals particles with different physico-thermal characteristics. It is evident that temperature stress is predetermined not only by temperature, but also by heterogeneity of structural components and anisotropy of their heat expansion and other properties on joints of grains or grains blocks, of which the body micro- and macrovolumes consist. It is necessary to consider that the temperature stress can influence the strain-stress state of the massif when plastic rocks drilling.

At a certain inhomogeneity of plastic rocks under the influence of a uniform temperature field, there will be temperature stress due to different physico-thermal characteristics of nonhomogeneous materials. Such local thermal stresses affect the rocks destruction when drilling with increase in borehole depth [7].

Conclusions

In the course of researches, it was found out that borehole tight stratum opening is followed by pressure reduction in the layer. Thus, the pressure drop intensity decreases with increase in distance from a borehole. The pressure inversion at the distance from the borehole is observed when borehole tight stratum opening. After borehole pressurization, the pressure in the massif of tight stratum in a bore zone increases, in peripheral zone it decreases, and then it is balanced throughout the whole area. Changes of pressure in plastic rock are of impulse nature. The thermal stress, which is called as residual, influences the destruction of rocks when drilling with increase in borehole depth.

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