INFLUENCE OF THE STRESSES ON FLOW RATE OF WELLS AND THEIR STABILITY

Vladimir Karev
Institute for Problems in Mechanics, Russian Academy of Sciences, Moscow, 119526, Russia

Summary The results of theoretical and experimental studies performed at the Institute for Problems in Mechanics of the RAS in the field of geomechanics of oil and gas wells are presented. Mathematical analysis of the stress state and size of fracture zones that arise near the well due to bottomhole pressure decrease is carried out. A new approach to the solution of geomechanical problems, based on tests of rock samples on the unique experimental facility Triaxial Independent Load Test System is proposed.

STRAIN-STRESS STATE NEAR THE WELL AND FILTRATION PROCESS

Numerous data on exploratory drilling and operation of oil and gas fields, especially at great depths, indicate that stresses appearing in the well bore zone have a significant effect on permeability and filtration processes in formations and, therefore, on oil and gas inflow rates. But the role of the stresses in forming of filtration processes in rocks is poorly understood now. Meanwhile, a number of scientists in the mechanics of the last century, Khristianovich [1] and others expressed the idea, that one of the decisive factors affecting the filtration in rocks is the process of deformation and destruction of rocks under the action of stresses arising in them.

Stress state near the well and contribution of filtration forces.
Early studies of the stress state, processes of deformation and fracture of rocks in the vicinity of mine workings were carried out in relation with the problems of development of solid mineral deposits, for example [2]. But the issues of the filtration impact, pressure gradient, compressibility, viscosity were not considered in these studies. Here are the results of analysis of the stress state and the size of fracture zones that occur in the vicinity of an oil well with a decrease in pressure on its face. The effect of additional mass forces due to the presence of pressure gradient in reservoir on the value fracture zones is studied for two conditions of the rock fracture. In the first case, the condition of the fracture is the achievement of a shear stress a certain limit – the criterion of Tresca. In the second case, the condition of local fracture can be presented in the form of Coulomb-Mohr criterion, according to which the achievement of the rock a limiting state on the site with the normal $\boldsymbol{n}$ is given by $\tau_n=[\tau]$, where $[\tau]$ – tensile strength, i. e. $[\tau]=k + S_n \operatorname{tg} \rho$, where S_n, τ_n – normal and shear stresses at the site, k – coefficient of coupling, ρ - friction angle of rock. The contribution of the compressibility and viscosity of the fluid in the stress distribution and size of fracture zones is determined for each criteria of fracture.
The following main conclusions are made on the base of the analysis.
1. In case of an incompressible fluid the size of fracture zone increases with the growth of pressure gradient which causes flow into the well. Radius of fracture zone can be significantly increased for sufficiently weak rocks. This finding is of a great importance in terms of selection the optimum operating conditions of the wells, since the permeability of rocks, especially sandstones, essentially depends on the stresses acting in them – it can irreversibly increase or decrease.
2. The account of the compressibility shows that an increase effective compressibility of the fluid extends the size of the fracture zone.
3. Accounting for increasing the viscosity of the fluid with growth pressure has opposite effect, i.e. reducing the size of the fracture zone. However, since the effect of pressure on the viscosity is less then on the density of the fluid, the change in the compressibility has greater impact on the size of the fracture zone.

The experimental study of the effect of stress-strain behavior on the filtration properties of rocks.
It is impossible to answer the question of how the stress-strain behavior affects permeability of some specific rock types using calculations because this depends on the properties of the rock itself. Such dependence can be studied using a unique experimental apparatus developed at the Institute for Problems in Mechanics of the Russian Academy of Sciences - Triaxial Independent Load Test System (TILTS). The facility allows independent loading of cubic rock samples with a 40 or 50 mm face in three axes, which is possible due to the original kinematic structure used in the design of the load assembly. Permeability measurements are performed in a continuous mode during the test of rock samples. This offers the possibility to recreate any stress conditions that appear in the bottomhole zone when the well is being drilled, completed, or operated during the tests and to study their effects on the filtration properties of rocks.
The rocks that form the reservoir of oil and gas fields are characterized by strong dependence of the filtration properties on pressure drawdown, and, changes are irreversible starting from a certain level of pressure in the well and accordingly the value of shear stresses in the rock. The effect of irreversible permeability increase by forming of micro and macrocracks was found for many types of rocks such as fine and medium sandstone with a low clay content, siltstone and limestone [3]. This effect got the name geoloosening and formed the basis of a new method to increase

the production rate of oil and gas drilling – the geoloosening method [4]. It was employed at several dozens of wells on fields in West Siberia and the Perm Region and showed high efficiency.

DIRECTIONAL AND HORIZONTAL WELLBORE STABILITY

A method has been developed to identify parameters for safe directional and horizontal drilling and operation of horizontal wells. It's based on direct physical TILTS modeling of the conditions that appear in the vicinity of the wells during drilling and operation. The relationship between well stability and well geometry is due to anisotropy of elastic properties and especially strength properties of rocks. Destruction of the borehole wall rock is related to higher shear stresses in bedding planes, which are surfaces of weakness. At some hole angle depending on the properties of the rock, depth and bottomhole pressure, shear stresses in the bedding plane reach critical values and trigger destruction of borehole walls.

According to calculations, the points where the vertical plane passing through the borehole axis crosses a borehole wall are the most dangerous areas in terms of destruction [5]. For this reason, changes in principal stresses at such points triggered by changes in borehole pressure were selected as a sample load program for TILTS modeling the conditions in the vicinity of the well at various hole angles.

In order to study stability of directional wells, samples are cut out of core material above the occurring rocks. The samples should be cut at different angles to the vertical axis. Bottomhole pressure and, respectively, mud density at which the rock is destroyed is determined for each hole angle using the sample cut at this angle.

The studies at the Ulyanovskoye field in West Siberia are given here as an example. Fig. 1 shows creep diagrams for several rock samples cut at different angels. During the tests of each of the samples, when radial stress reached the bottomhole pressure value corresponding to mud density of 1.2 g / cm^3, loading was stopped and changes in sample strain were measured over time. As one can see from the diagrams, the sample cut at a 0° angle did not creep at all; the samples cut at 15° and 30° angles demonstrated limited creep, while the samples cut at 45° and 60° angles reached a preset load point, started creeping at an ever-increasing rate, and were finally destroyed. Fig. 2 shows creep diagrams at mud density of 1.12 g / cm^3, which corresponds to lower bottomhole pressure and, therefore, higher stresses in the rock in the vicinity of the well. As one can see from the graph, unlimited creep and destruction are observed at smaller sample angles, starting from 30°. The findings are quite consistent with practical data.

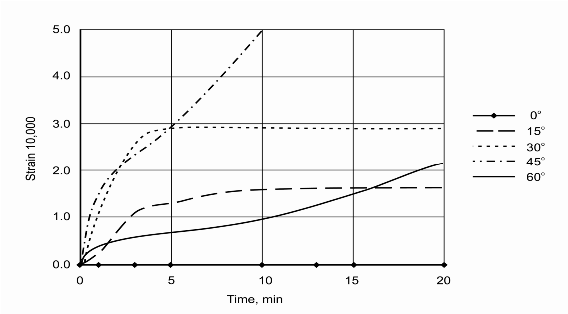

Fig.1

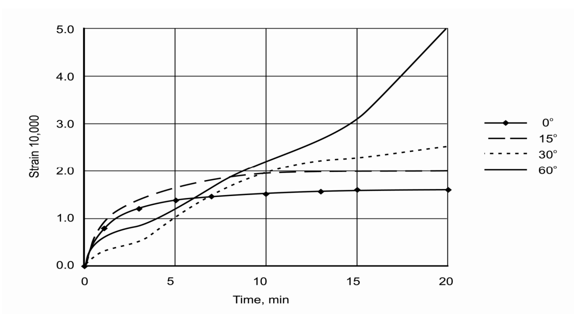

Fig.2

Such studies have been conducted for a number of major Russian companies such as Gazprom, Lukoil, Surgutneftegas, and the findings of the studies have been confirmed by practical experience. In 2009, at the request of Shtokman Development, an international company created by Gazprom, Total and StatoilHydro, there were conducted studies which offered the opportunity to validate engineering and process solutions for optimization of the development strategy and policy for the Shtokman gas condensate field located offshore in the Barents Sea.

CONCLUSIONS

Stresses in rock matrix and filtration processes in reservoir have a significant mutual influence. The study of the behaviour of rocks under the stress change is a key to solving geotechnical problems of oil and gas production.

References

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