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About impact of clogging phenomena on well productivity

O wpływie zjawiska kolmatacji na wydajność odwiertu

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ABSTRACT: During the opening of a productive formation by drilling, penetration of clay particles from the drilling fluid into the leading filtration channels of the rock occurs. As a rule, productive formations are opened at pressures that are significantly higher than the formation pressure. The amount of hydrostatic repression depends on the density of the drilling fluid, the height of the liquid column, and the reservoir pressure. A classic example of the latter is the problem of studying changes in reservoir properties that occur at the drilling stage, where relatively small particles of drilling fluid penetrate along with the flow into the pore space. A decrease in the bottomhole zone permeability in oil wells leads to a significant decrease in oil production rates, and sometimes to their complete stop, which ultimately significantly affects the total oil recovery and economic indicators of the oil fields' development. The decrease in permeability can be caused by many factors:

- clogging of the bottomhole zone of the productive formation in the process of drilling a well;
- formation of a crust in perforated channels during cumulative perforation;
- colmatation of the bottomhole zone of the productive formation during the operation of the well;
- clogging of perforated channels during well killing and subsequent clogging;
- formation of deposits of paraffins and asphaltenes in the pores of the rock of the bottomhole zone of the well. Bottomhole zone damage (clogging) significantly affects the productivity of wells, and the permeability of the formation, determined by the results of hydrodynamic studies. At the same time, clogging is understood as damage of the bottomhole zone with drilling fluid when opening the productive formation, and deterioration of the properties of the bottomhole zone during cementing, perforation of the productive interval, swelling of clays, etc.

This paper presents an analysis of laboratory and field studies of the influence of clogging on the productivity of wells when opening layers with different capacitive and filtration properties, and also provides an analytical estimation of this effect, both for vertical and horizontal wells.

Key words: clogging, flocculation, bottomhole zone, permeability, damage, dispersion medium, sand plug.

STRESZCZENIE: W czasie udostępniania formacji produktywnej poprzez wiercenie następuje przenikanie cząstek ilastych z płuczki wiertniczej do przestrzeni porowej skały. Formacje produktywne są z reguły udostępniane przy ciśnieniach, które są znacząco wyższe niż ciśnienia złożowe. Wielkość przeciwciśnienia hydrostatycznego zależy od gęstości płuczki wiertniczej, wysokości słupa cieczy oraz ciśnienia złożowego. Klasycznym przykładem tego ostatniego jest problem badania zmian właściwości zbiornikowych na etapie wiercenia, kiedy to stosunkowo niewielkie cząstki ilaste przenikają, wraz z płuczką wiertniczą, do przestrzeni porowej. Spadek przepuszczalności w strefie dennej odwiertów naftowych prowadzi do znaczącego spadku wydajności produkcji ropy, a czasem nawet do całkowitego zatrzymania wydobycia, co ostatecznie znacząco wpływa na wielkość całkowitego wydobycia ropy oraz wskaźniki ekonomiczne udostępnienia złoża ropy. Spadek przepuszczalności może być spowodowany wieloma czynnikami:

- kolmatacją strefy dennej w obrębie formacji produktywnej na etapie wiercenia otworu;
- tworzeniem się warstwy osadu w perforowanych kanałach podczas skumulowanej perforacji;
- kolmatacją strefy dennej formacji produktywnej w czasie eksploatacji odwiertu;
- blokowaniem kanałów perforacyjnych w czasie zatłaczania odwiertu i później;
- tworzeniem się osadów parafin i asfaltenów w porach skały w strefie dennej odwiertu. Uszkodzenie strefy dennej odwiertu znacząco wpływa na wydajność odwiertów oraz przepuszczalność formacji złożowej, określoną przez wyniki badań hydrodynamicznych. Uszkodzenie jest jednocześnie rozumiane jako zanieczyszczenie strefy dennej płuczką wiertniczą przy udostępnianiu formacji produktywnej, pogorszenie się właściwości w strefie dennej w czasie cementowania lub perforacji interwału złożowego, pęcznienie iłowców, itp.

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Niniejszy artykuł przedstawia analizę badań laboratoryjnych i terenowych nad wpływem zjawiska kolmatacji na wydajność odwiertów przy udostępnianiu warstw o różnych właściwościach pojemnościowych i filtracyjnych, jak również analityczne oszacowanie tego efektu, zarówno dla odwiertów pionowych, jak i horyzontalnych.

Słowa kluczowe: kolmatacja, flokulacja, strefa denna, przepuszczalność, uszkodzenie, medium dyspersyjne, korek piaskowy.

Introduction

High filtration resistance in the bottomhole zone of a well may be due to the geological characteristics of the oil reservoir, the physical properties of the produced fluid (high-viscosity and high-paraffin oils), or factors that cause partial blockage of the microchannels of the porous medium and, accordingly, worsen the permeability of the bottomhole zone of the well during various technological operations.

Such technological operations include:

- well drilling and casing string cementing;
- development and killing of wells (using drilling fluids and killing fluids);
- perforation;
- hydraulic fracturing (HF);
- repair and insulation works (RIW);
- well operation, etc.

During the opening of the productive formation by drilling, penetration of clay particles from the drilling fluid into the conductive filtration channels of the rock occurs. As a rule, productive formations are opened at pressures that are significantly higher than the formation pressure. To prevent oil and gas shows during drilling, it is necessary to create a hydrostatic pressure of the liquid column (drilling mud), which is much higher than the reservoir pressure. The value of hydrostatic repression depends on the density of the drilling fluid, the height of the liquid column, and the reservoir pressure (Collins, 1961; Mavlyutov et al., 1987).

In addition to the hydrostatic pressure of the liquid column during drilling, hydrodynamic repressions can occur on the formation, often of a pulsating nature. They occur during tripping operations, pulsating fluid supply, pump stop, and stuffing box formation in the annulus and on the bit (Mikhailov, 1976; Mirzajanzade and Yentov, 1985). It has been established that the hydrodynamic pressure drop increases with the depth of the drill string descent, the increase in the speed of the descent of the string, and the increase in the number of round trips. Particularly high values of hydrodynamic pressures occur during the rapid descent of the drill string, and they can reach 4–10 MPa.

The swelling of clay particles is a rather complex phenomenon that occurs when fresh water or water of other mineralization penetrates into the formation. It occurs as a result of a violation of the physicochemical balance between the clay, formation water, and water penetrating into the formation for any reason (Mikhailov and Yanitsky, 1980).

Under certain conditions, when water and oil and oil and water come into contact, flocculation and settling of solid particles in the bottomhole zone and gradual blockage of the pore space can occur.

Flocculation is a type of coagulation in which coarse particles of the dispersed phase are large loose flocculent aggregates – floccules (Bulatov, 1998; Bigaliyev, 2001), capable of rapid settling or floating up (Zhigach et al, 1962).

Synthetic polymeric materials, in particular polyacrylamide, are often used as flocculants. Polymer macromolecules are simultaneously adsorbed on several dispersed particles with the formation of bonding bridges between the particles of the dispersed phase, as if gluing these particles into large aggregates (Kotyakhov, 1970; Yasashin, 1979).

Of the inorganic flocculants, active silicic acid is used (Gray et al., 1980).

The bridging mechanism and the greater friability of the resulting aggregates due to the size of the flocculant macromolecules distinguish flocculation from ordinary coagulation, in which the particles are directly aggregated (Miller, 1971; Gray et al., 1980). When purifying natural waters, high-molecular flocculants are often used in conjunction with coagulants: flocculants "cross-link" microflakes resulting from the introduction of coagulants.

At the same time, microflakes combine into large aggregates, the sedimentation of which proceeds much faster (Shevaldin, 1988).

Suspended substances can be deposited in the form of a film on the inner surface of the pore space. This phenomenon is observed both during the opening of the oil reservoir, and in the process of well development using water or mud. As a result, a crust is formed on the walls of the wellbore, consisting of solid particles of the drilling fluid with sizes larger than the pores of the productive formation, and, therefore, not penetrating into the channels of the porous medium.

The filtration of water from the mud into the reservoir occurs when the size of the pore channels of the rock is much smaller than the size of the solid particles dispersed in the solution (Mikhailov, 1978).

In the processes of the workover and underground workovers of wells, water or mud is most often used as killing fluids. If the oil reservoir has low permeability and is also characterized by the content of clay fractions, then the physical contact of the bullhead liquid (BL) with the reservoir rock leads to the formation of fine grains of sand and silt in the bottomhole zone. Under certain conditions, they clog part of the pore space of the rock. The same effect can be observed during well development when water or a water-based fluid is used as the flushing fluid.

During repair and isolation works, when the technological scheme involves pumping working agents into the well and forcing them into the isolated interval, a complex hydrodynamic situation arises in the bottomhole zone of the treated wells, due to the physical contact of the insulating material (gelling compositions) with the reservoir rock. If the treatment is carried out in marginal production wells with low reservoir pressure and low permeability of the oil reservoir, the negative effect is enhanced.

The weak resistance of reservoir rocks to seepage erosion during well operation causes the destruction of the formation skeleton and the entry of sand particles to the bottom of the well. The largest sand particles are deposited at the bottom of the well, forming a sand plug. The resulting sand plug partially or completely covers the well filter (Collins, 1961). Being above the roof of the productive horizon, due to the small section of the wellbore, it acts as a downhole choke, which creates a significant resistance to the upward flow of fluid. If, in addition, it partially or completely overlaps the well filter, then even more additional resistance is created that prevents the movement of filtration flows in the formation layers located against the sand plug. Moreover, the lower part of the formation is under a greater back pressure than the upper one, which is equivalent to a decrease in the magnitude of the drawdown created in the well.

Based on theoretical and laboratory studies and field data, it was found that the clogging of rock filtration channels with solid particles of clay mud, particles of cuttings, sand, silt, etc., in the process of the above technological operations, reduces the relative permeability for oil by 5–6 times. In this case, the depth of penetration of the drilling mud filtrate has a great influence. Figure 1 shows the dependence of the effect of mud on the oil permeability of cores.

Figure 2 shows the dependence of the decrease in well productivity based on the depth of contamination of the bottomhole zone.

Thus, if in a reservoir with a permeability k = 0.020 μm^2 it decreased to the value k_1 = 0.001 μm^2 within a radius of R = 25 cm (respectively, $R - r_w$ = 15 sm), then the well productivity decreases not only by 20–50 times, but also there is an even greater decrease and over a much larger radius. Such cases are noted during the development of new wells, when they can be put into operation with industrial flow rates only after treatments aimed at eliminating the damage.

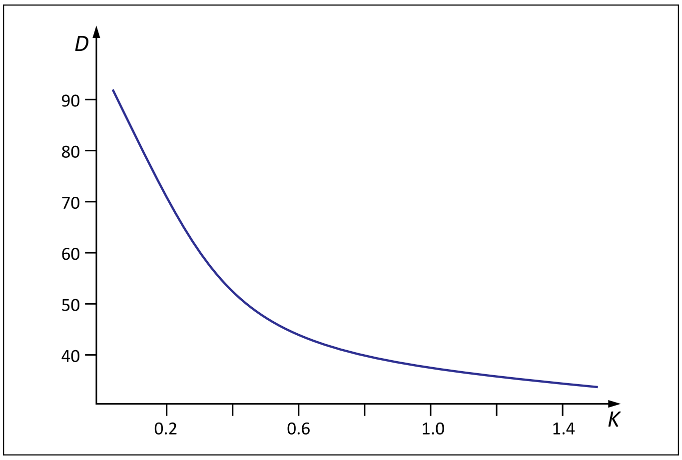

Figure 1. Influence of slurry on core permeability

Rysunek 1. Wpływ zawiesiny na przepuszczalność rdzenia

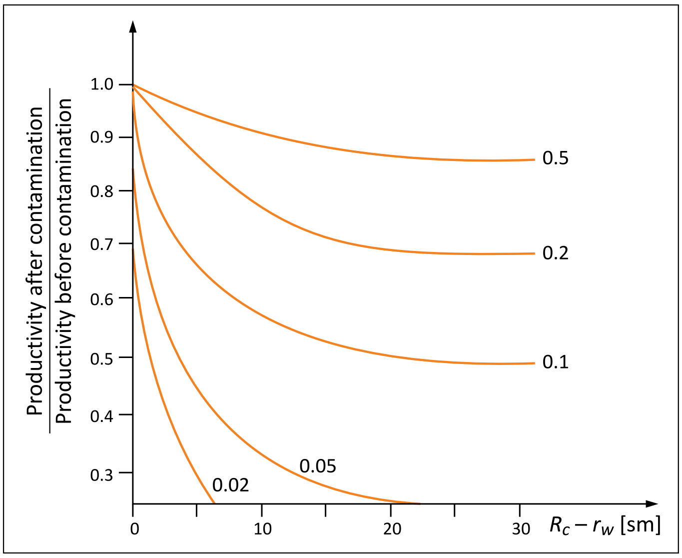

Figure 2. Decrease in well productivity depending on the depth of damage

Rysunek 2. Spadek wydajności odwiertu w zależności of głębokości zanieczyszczenia

Coagulation structures are formed when the dispersed system loses its aggregative stability; with a sufficient content of the dispersed phase, reinforcement of the entire volume of the dispersed system is provided. The corresponding content of the colloidal dispersed phase, capable of "hardening" the liquid dispersion medium, can be very small (especially in the case of sharply anisometric particles); for example, only a few percent by weight for bentonite clays, and still much less for filamentous particles. A characteristic property of coagulation structures, along with their relatively low strength, is their reversibility with respect to mechanical influences – the ability to spontaneously recover after mechanical damage (in a mobile dispersed medium); this property is called thixotropy.

Coagulation (from the Latin "coagulatio"– coagulation, thickening) and flocculation (from the Latin flocculi– shreds, flakes) are physicochemical processes of the adhesion of small particles of dispersed systems into larger aggregates (Bigaliyev, 2001) under the influence of cohesive forces with the formation of coagulation structures.

Coagulation leads to the precipitation of a precipitate from the colloidal solution or to gelation. Coagulation can be either spontaneous (ageing) with separation of the colloidal solution into a solid phase and a dispersed medium and reaching a state of minimum energy, or artificially induced using special reagents (coagulants or flocculants).

Coagulation is the process of reducing the degree of dispersion and the number of particles of a dispersed system by the sticking together of primary particles. Coagulation usually results in precipitation (sedimentation) of the dispersed phase or a change in the properties of the primary disperse system.

Coagulation disperse structures are formed by pigments and fillers of varnishes, paints, and polymers. A typical example of thixotropic structures is the spatial networks that appear in clay dispersions during their coagulation under the action of electrolytes.

The theory of coagulation (M. Smoluchovsky) was developed on the basis of the following concepts: the particles of the dispersed phase perform Brownian motion independent of each other until, when two particles approach each other, the distance between their centres becomes equal to the so-called radius of the sphere of influence d. This value is approximately equal to the sum of the particle radii, which corresponds to their direct contact. At this distance, interaction forces between particles appear (immediately, abruptly), as a result of which the possibility of their aggregation is created. As a result of coagulation, only two particles interact, since the probability of a collision of a larger number of particles is very small. Thus, single particles collide, forming double, single with double, double with each other, triple with single, etc. particles. Such a representation of the coagulation process allows us to formally reduce it to the theory of bimolecular chemical reactions.

Discussion

Skin effect

The skin effect is understood as a change in the permeability of filtration channels due to their damage (cleaning) with solid particles contained in the filtering fluid. The very process of the damage (cleaning) of filtration channels with mechanical particles is called clogging (de-clogging).

This is of particular importance for the bottomhole zone of the well, in which the prevailing energy losses occur, which are fixed, in particular, in the study of a well operating in a non-stationary mode.

Clogging of the bottomhole zone of the well (BHZ) can occur at various periods of the life of the well, starting from its initial opening. In the process of initial opening and subsequent cementing, not only the filtrates of the applied solutions but also particles of the dispersed phase of clay and cement solutions, which, deposited in the filtration channels, reduce their permeability, enter the NWB (Near Well Bore) zone. During the initial opening for repression, the destruction of the cementing substance of the terrigenous reservoir in the near-wellbore zone and clogging of the filtration channels is also possible.

During the operation of a production well, clogging is also possible due to obliteration, and the deposition of asphaltene-resinous-paraffin components of oil, salts, etc. During the operation of an injection well, clogging is possible due to deposits in the bottomhole zone of mechanical particles coming from the water injected during pressure maintenance, as well as other solid impurities (salts, pipe corrosion products, etc.) (Mikhailov, 1987).

The process of clogging (de-clogging) of the BHZ and its causes have been studied quite well and various technologies have been proposed that reduce the negative impact of this phenomenon on the filtration characteristics of the system.

Study of the clogging process during the opening of oil and gas reservoirs

During the construction and operation of wells, technological fluids that are used at the stage of well completion are of great importance. In this case, it is necessary to highlight the stages when process fluids are in contact with the productive reservoir: opening a productive section, perforating the casing, carrying out cementing to ensure the tightness of the well, the process of well development and measures to intensify oil production (Kaspersky, 1971).

The degree of contamination of the bottomhole zone depends on the properties of the drilling fluid, its density, viscosity, and water loss, as well as the properties of the porous medium, primarily on the permeability and duration of the process of opening the productive interval.

A lot of scientific and practical research is devoted to the choice of flushing fluids. To a lesser extent, the damage of the bottomhole zone during the perforation of the productive interval and the cementing of the casing string has been studied. To date, scientifically based recommendations have not been developed to determine the degree and radius of damage of the bottomhole zone for various capacitive and filtration properties of a porous medium. There are no methodological recommendations justifying the degree of stimulation of the damaged zone during well flushing in the process of its development with different filtration properties of the porous medium. This problem becomes more complicated if there are interlayers that are heterogeneous in terms of their permeability in the productive interval. Such a degree of knowledge of the influence of clogging of the bottomhole zone on the productive characteristics of wells significantly reduces the reliability of the predicted indicators of the development of oil and gas fields at the design stage. Almost completely unexplored are the issues of damage of the bottomhole zone during the development of fields with horizontal wells. In particular, when using horizontal wells, the degree of damage of the bottomhole zone increases due to the longer duration of the drilling process associated with the length of the horizontal wellbore. The degree of damage and the radius of this zone are not identical in the horizontal and vertical directions, which is associated with the formation anisotropy. The degree of damage of the bottomhole zone is significantly affected by the location of the horizontal wellbore along the thickness of the formation, its profile, and the length of the opening of each interlayer, which is proportional to the oil reserves and inversely proportional to its permeability (Mikhailov, 1976, 1978). A decrease in well productivity as a result of the penetration of drilling fluid into a productive formation as well as methods and technologies to reduce the impact of bottom-hole zone clogging on well productivity have been studied by domestic and foreign researchers for more than 50 years. The most significant in terms of the depth of the analysis and generalization of the studies carried out in this direction are the following works: (Zhigach et al., 1962; Kotyakhov, 1970; Miller, 1971; Bobelyuk, 1979; Yasashin, 1979; Gray et al., 1980; Bulatov, 1998; Bigaliyev, 2001).

Depending on the composition, properties of the porous medium, and the drilling fluid, the size of the contamination zone is due to the swelling of clays in the production reservoir, the value of capillary pressure associated with the fluid loss of the drilling fluid and the size of the pore channels, the formation of an oil-water emulsion, clogging of the pore channels with solid particles of the clay solution, etc.

As a rule, reservoirs formed by sandstones contain shale inclusions, due to which the concept of the shale coefficient of reservoirs was introduced in the industry literature. When opening such reservoirs with water-based drilling fluid, water interacts with clay particles, as a result of which these particles swell. An increase in the size of clay particles significantly reduces the permeability of the formation in the swelling zone. Depending on the composition and properties of clays in productive reservoirs, as well as the amount of fluid loss of the flushing fluid, the filtration characteristics of these reservoirs can significantly decrease, and in some cases even exclude the possibility of the oil inflow to the well. Therefore, when justifying and choosing a drilling fluid formulation, it is necessary to take into account the composition and properties of clays in productive reservoirs.

The negative impact of clogging on the productivity of wells during the opening of reservoirs with different mineralogical, capacitive, and filtration properties has been established by numerous laboratory and field studies. This served as the basis for conducting theoretical and experimental studies to reduce the impact of clogging on the bottomhole zone, as well as for developing recommendations for cleaning this zone from the effects of pollution. For example, Kotelnikov (1969) proposed to open a productive interval with flushing with polymer solutions, and in the Shevaldin's work (1988) a method for choosing surfactants for flushing fluids when opening productive horizons is recommended. Restoration of the reservoir properties of the bottomhole zone by creating cyclic drawdowns in the formation is recommended by Minkhairov et al. (1986). However, the recommendations proposed in these works do not guarantee complete cleansing of the bottomhole zone from clogging and are more effective when opening high-permeability reservoirs. In a significant number of scientific studies devoted to reducing the effect of clogging (Zhigach et al., 1962; Kotelnikov, 1969; Miller, 1971; Tokunov and Mukhin, 1977; Minkhairov et al., 1986), it is recommended to use oil-based drilling fluids or apply surfactants. The use of an oil-based drilling fluid virtually eliminates the possibility of clay swelling when opening clayed sandstones. The addition of surfactants to a water-based drilling fluid reduces the adsorption activity of water by clay particles, and also improves the possibility of cleaning the near-wellbore zone from contamination during the well development. The paper (Kotelnikov, 1969) presents the physical and chemical bases for the use of surfactants in the development of oil fields with the maintenance of the reservoir pressure. An analysis of some of the previously listed works (Zhigach et al., 1962; Kotyakhov, 1970) shows that the use of surfactants leads to a significant decrease in clay swelling.

Water intrusion into the reservoir during the opening process and its subsequent displacement from this zone during well development with oil, leads to saturation of the bottomhole zone with two phases, which reduces the phase permeability for oil. The degree of influence of water on well productivity depends on the interaction of the water and the porous medium, in particular, on its hydrophilicity, as well as the structure of the oil and water flow. Theoretically, it is assumed that in pore channels, depending on their size and the properties of the fluids filling them, three types of flow structures are possible: jet, emulsion, and jet-emulsion – simultaneously in different channels of the porous medium. Schematically, two main types of flow structures are shown in Figure 3. The reasons for the formation of a water-oil emulsion in a porous medium are given, among others, in the works of Kotelnikov (1969)

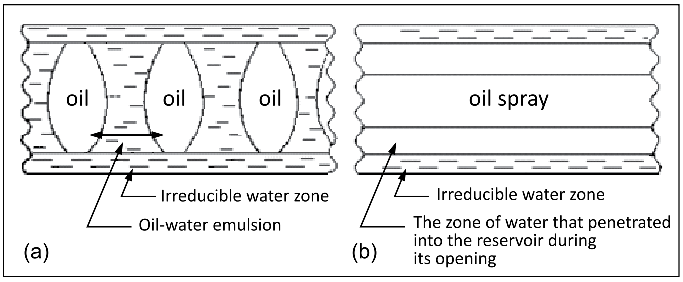

Figure 3. Scheme of the movement of oil and water through porous channels with mixed (emulsion) (a) and jet (b) flow structures

Rysunek 3. Schemat przepływu ropy i wody przed kanały porowe ze strukturami przepływu mieszanego (emulsja) (a) i strumieniowego (b)

and Kotyakhov (1970). In these and other works, it is assumed that the formation of an oil-in-water emulsion is associated with the dispersion of one liquid phase into another, as well as with the fragmentation of oil droplets or lenses through small channels. The above information mainly covers the physical nature of the clogging process and the possibility of reducing its impact on well productivity, which are mainly focused on the choice of the drilling fluid formulation and the replacement of water-based solutions with hydrocarbon ones.

The theoretical foundations of the influence of bottomhole zone damage on the productivity of oil wells have been studied to a lesser extent than the scientific and practical ones associated with the development of an appropriate drilling fluid formulation. Considerable attention in the published works is paid to the technologies of opening the productive interval, which helps to reduce the impact of clogging on the productivity of the well. Often such technologies are recommended for specific oil-bearing objects.

The development of theoretical foundations for determining the effect of damage of the bottomhole formation zone during its opening on well productivity is fraught with difficulties due to the lack of information about the following: the shape and size of the damaged zone with different filtration properties of the formation in the bottomhole zone; phase permeability in the damaged zone; the structure of the flow of oil and water in the bottomhole zone in channels with different sizes; the degree of stimulation of the damaged zone of the well in the process of its development. For these and other reasons, simple analytical solutions of oil inflow to the well, taking into account the impact of damage of the bottomhole zone, even when opening with a vertical wellbore, have not been obtained. In general, two zones can be distinguished (Figure 4): the bottomhole zone with known dimensions R_{nwb} and permeability k_{nwb}, and outside it with R_c–R_{nwb} and permeability k_{res}.

In the case of plane-radial filtration, the influence of damage can be taken into account according to the following formula:

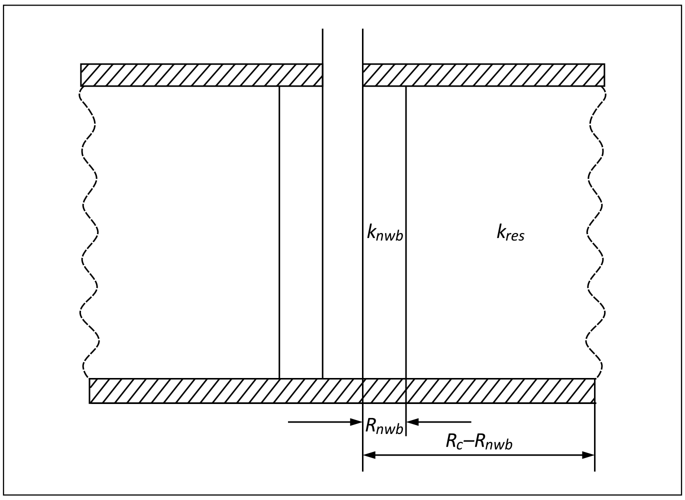

Figure 4. Scheme of oil inflow to the well, taking into account the damage of the bottomhole formation zone during the opening

Rysunek 4. Schemat przypływu ropy do odwiertu, uwzględniając uszkodzenie formacji w strefie dennej w czasie udostępniania

$$p_c - p_{bh} = \frac{\mu_o Q_o}{2\pi h k_{res} k_{nwb}} \left(k_{res} \ln \frac{R_c}{R_{nwb}} + k_{nwb} \ln \frac{R_{nwb}}{R_w} \right) \qquad (1)$$

where:

$p_c - p_{bh}$ – is the drawdown;

μ_o – oil viscosity;

Q_o – oil flow rate;

h – layer thickness;

k_{re} and k_{nwb} – respectively, the permeability of the formation and bottomhole zone;

R_c, R_{nwb} and R_w – respectively, the radius of the contour of the zone drained by the well, the contaminated near wellbore zone, and the radius of the well.

It follows from this formula that, at a given production rate, a decrease in reservoir permeability leads to an increase in drawdown. According to (1), by setting different values of R_{nwb} and k_{nwb}, it is possible to estimate the impact of bottom-hole zone damage on the value of the production rate or drawdown on the formation.

An analytical assessment of the impact of bottomhole zone clogging on well productivity is approximately given in (Bobelyuk, 1979; Rabinovich, 1989; Bigaliyev, 2001) when opening productive formations with a vertical wellbore, without taking into account the heterogeneity and anisotropy of each interlayer. Similar work was done by Zotova and Aliyev (1980) for horizontal gas wells that penetrated formations of uniform and heterogeneous thickness, taking into account the anisotropy parameter.

The influence of bottomhole zone clogging on the productivity of horizontal oil wells in the exact formulation has not been studied to date. The mechanical transfer of existing methods for assessing the impact of clogging on the productivity of vertical oil wells to horizontal wells is unacceptable due to the difference in permeability values in the vertical and horizontal directions and the different filtration geometry to the horizontal wellbore. The location of the horizontal wellbore along the reservoir thickness and its profile have a significant impact.

Accounting for almost all the geological, technical and technological factors in determining the effect of bottomhole zone clogging on the productivity of a horizontal well is possible using a numerical method.

The numerical method proposed by Bondarenko (2007a) for studying the effect of clogging of the bottomhole zone of a well using models of fragments of oil and gas fields with different capacitive and filtration characteristics makes it possible to establish the relationship between the productivity of a horizontal oil well and the following parameters:

- the size of the clogging zone during the opening of homogeneous and multi-layer inhomogeneous interlayers in thickness;
- permeability of interlayers;
- anisotropy parameter;
- thickness of interlayers;
- design, i.e. the length and diameter of the horizontal shaft;
- the location of the horizontal shaft in thickness;
- opening profile;
- pressure change along the length of the horizontal wellbore;
- change in the properties of the porous medium and fluids saturating it with changes in reservoir and bottomhole pressures;
- influence of capillary and gravitational forces;
- non-stationarity of the filtration process;
- the presence or absence of interaction between interlayers, etc.

Mathematical experiments (Bondarenko, 2007b), carried out on models of fragments of homogeneous reservoirs with an absolute permeability of 0.5; 0.1 and 0.02 mcm^2 penetrated by horizontal wells made it possible to establish that with a symmetrical arrangement of a horizontal wellbore in a reservoir with a permeability of 0.5 mcm^2, the well flow rate Q = 1553 thousand m^3/day without clogging was obtained with drawdown on the reservoir Δp = 0.249 MPa. To maintain this flow rate when the bottomhole zone is clogged with drilling fluid within a radius of $0.25 \leq R \leq 16.25$ m, the drawdown on the reservoir increases to $\Delta p \approx 1.2$ MPa and exceeds the drawdown obtained without clogging by almost 5 times. It should be noted that the most intensive drawdown growth occurs at R_{clog} = 0.25 m, when the growth factor is $\Delta P_{clog} / \Delta P_{without\ clog}$ = 3.95. A further increase in the radius of the clogging zone to R_{clog} = 16.25 m leads to an increase in the drawdown ratio to $\Delta P_{clog} / \Delta P_{without\ clog}$ = = 4.77 times, i.e., to an increase by 20%.

Similar mathematical experiments carried out on models of fragments of homogeneous reservoirs with an absolute permeability of 0.1 and 0.02 μm depression at a practically constant well flow rate, and at R_{clog} = 0.25 m, show the growth rate is 5.21 and 6.35 times, respectively, i.e. with the radius of the clogging zones $0.25 \leq R \leq 16.25$ m and the symmetrical arrangement of horizontal wells in thickness, with a decrease in the absolute permeability of the layers being penetrated, the drawdown increases.

The influence of the asymmetry of the location of the horizontal wellbore over the thickness of a homogeneous formation turned out to be more significant than the influence of clogging. This conclusion is valid for two reasons:

- clogging has the main effect in the zone with a radius R_{clog} = 0.25 m, and this zone remains even when the trunk is placed in the first cell from the top with a thickness h = 0.5 m;
- the influence of the asymmetric location of the horizontal wellbore in thickness becomes more intense with the thickness of the reservoir being penetrated $h \geq 10$ m.

Therefore, for the fragments with a thickness h = 104.4 m accepted in the simulation, the effect of asymmetry in thickness turned out to be more significant.

It follows from the above that the productive characteristic of the well depends, first of all, on the filtration properties of the interlayer in which the horizontal wellbore is located.

Conclusions

1. An analysis of the causes affecting the permeability of the geological formation in the bottomhole zones of wells revealed that clogging of the rock filtration channels with solid particles of clay mud, particles of cuttings, sand, silt, etc., in the process of various technological operations reduce the relative permeability for oil by 5–6 times.
2. Hydrodynamic studies of wells are a necessary tool for controlling the rational development of hydrocarbon fields and provide real information that allows one to quickly make the necessary decisions.

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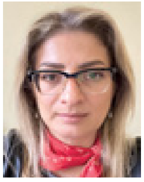

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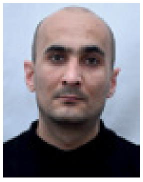

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